EVANSVILLE WATER AND SEWER UTILITY
AND
FOUR RIVERS RESOURCE CONSERVATION
AND DEVELOPMENT AREA, INC.

Volume 1
MAIN REPORT

PIGEON CREEK WATERSHED DIAGNOSTIC STUDY

MWH
MONTGOMERY WATSON HARZA

September 2001

PIGEON CREEK
WATERSHED DIAGNOSTIC STUDY
VOL. 1 – MAIN REPORT

Prepared for

Evansville Water and Sewer Utility
And
Four Rivers Resource Conservation and Development Area, Inc.

By

HARZA
Engineering Company

September 2001

EXECUTIVE SUMMARY

Pigeon Creek drains nearly 240,000 acres of southwestern Indiana to the Ohio River (Exhibit 1). Since settlement by Europeans, the landscape of the Pigeon Creek watershed has been altered dramatically. Over the decades, settler activities have changed the dynamic equilibrium of the creek and its upslope systems. The cumulative effect of these watershed changes on the aquatic ecosystem has been degradation of water quality, loss of floodplain storage, diminished wildlife populations, and decreased aesthetic and recreational values. This diagnostic study was performed to evaluate the severity of these changes and to recommend further studies and project investments to improve water quality in Pigeon Creek.

The specific objectives and financers of this study included:

1. The Pigeon Creek watershed upstream of Evansville is subjected to nonpoint source pollution (NPS) from agricultural, mining and other land uses detrimental to stream health. The Soil and Water Conservation Districts (SWCD) of Vanderburgh, Gibson and Warrick Counties have commissioned a diagnostic study of NPS in the watershed under the sponsorship of the Department of Natural Resources' Lake and River Enhancement Program and the Department of Environmental Management's (IDEM) Nonpoint Source Program.
2. The Evansville Water and Sewer Utility (EWSU) is required under their National Pollutant Discharge Elimination System (NPDES) Permit to prepare a Stream Reach Characterization and Evaluation Report (SRCER) that addresses combined sewer overflows (CSOs) in its service area drained by Pigeon Creek (Exhibit 2).

The SWCDs and EWSU retained Harza Engineering Company to perform an integrated study of point and nonpoint pollution sources from rural, upstream areas as well as downstream urbanized, largely impervious areas.

ENVIRONMENTAL SETTING

We obtained the latest, most complete digital land use/land cover data available from the U.S. Fish and Wildlife Service's Gap Project. These data indicate that about half of the Pigeon Creek watershed is row crop agriculture and about 5% is urban land. Interestingly, about 7.5% of the watershed remains as wetlands or open water. This is substantially less than pre-settlement conditions. We have tabulated the land use/land cover figures below and Exhibits 5 and 6 provide additional details.

LAND USE IN THE PIGEON CREEK WATERSHED
(Source: Indiana Gap Project)

Land Use	Area (ac)	Percentage
Urban	10,847	5%
Agriculture Row Crop	113,055	48%
Agriculture Pasture/Grassland	46,728	20%
Upland Forest and Woodlands	38,114	16%
Wetland Forest and Woodlands	11,237	5%
Other Wetlands and Water	6,326	3%
Other Non-vegetated	8,920	4%
Total	235,226	100%

Corn, soybeans, wheat, and hay are the most common crops grown in the study area. According to the Agricultural Census for Indiana, in 1997, Gibson County had 579 farms totaling 232,839 acres, Warrick County had 356 farms totaling 98,549 acres, and Vanderburgh County has 271 farms totaling 72,112 acres.

Evansville is the largest city in the watershed, with a 1990 population of 126,272, residing in 53,058 households. Evansville has a diversified economy, with health care, manufacturing, education and retail providing much of the local employment base. Evansville is an older city, and has a combined sewerage system throughout much of its area. Wet weather overflows discharge combined sewage to Pigeon Creek at eight locations.

WATERSHED BIOASSESSMENT

We surveyed the physical habitat, water quality and benthic community at 36 sites in the watershed. The 36 survey sites were selected to represent the 26 subwatersheds (14-digit hydrologic unit codes) in the study area. The physical habitat survey method used was the same as that used by IDEM in its surface water assessment program, the Qualitative Habitat Evaluation Index (QHEI). All sites surveyed failed to meet IDEM's QHEI score for full support of aquatic life, indicating a watershed-wide need for improved physical habitat. Water samples were collected for analysis of nutrients, suspended solids, coliform bacteria, and other parameters. The Rapid Bioassessment Protocol, a standardized assessment tool developed by the U.S. Environmental Protection Agency (USEPA), was performed to evaluate the health of the macroinvertebrate community in streams of the watershed. One of the metrics in that protocol is the modified Family Biotic Index (FBI), developed to detect organic pollution. The FBI is a product of pollution tolerance values for family levels and the quantity of individuals within each family. Key indicators of stream biotic integreity were judged to be coliform bacteria levels, nutrient concentrations, suspended solids concentrations, substrate siltation scores and the FBI. The FBI was selected as the key benthic indicator as it incorporates both diversity and pollution tolerance.

Using these five key stream biotic integrity health variables, we ranked the 36 monitoring sites into four groups. The more healthy subwatersheds are those included in the first quartile and warrant protection against degradation: Smith Fork (subwatersheds 20 and 21), West Fork Pigeon Creek (subwatershed 24) and Big Creek (subwatersheds 17, 18 and 19). Sites in the fourth quartile are considered the most degraded sites.

RELATIVE TRIBUTARY BIOTIC INTEGRITY

First Quartile		Second Quartile		Third Quartile		Fourth Quartile	
Site	**Water Body**	**Site**	**Water Body**	**Site**	**Water Body**	**Site**	**Water Body**
SF3	Smith Fork	PC4	Pigeon Creek	WF2	West Fork	HC1	Hurricane Creek
BG1	Big Creek	PC5	Pigeon Creek	WF3	West Fork	PC8	Pigeon Creek
BG2	Big Creek	PC12	Pigeon Creek	PC13	Pigeon Creek	BC3	Bluegrass Creek
PC15	Pigeon Creek	SC1	Squaw Creek	PC1	Pigeon Creek	WD1	Weinsheimer Ditch
SF1	Smith Fork	WF1	West Fork	PC3	Pigeon Creek	PC7	Pigeon Creek
SF2	Smith Fork	PC2	Pigeon Creek	BC1	Bluegrass Creek	BC2	Bluegrass Creek
PC14	Pigeon Creek	PC11	Pigeon Creek	LP1	Little Pigeon Creek	PC6	Pigeon Creek
SA1	Sand Creek	PC16	Pigeon Creek	LC2	Locust Creek	PC9	Pigeon Creek
LP2	Little Pigeon Creek	LC1	Locust Creek	UN1	Unnamed Tributary	SD1	Stollberg Ditch

SOURCES OF POLLUTANTS

We examined point and nonpoint sources of pollution throughout the watershed. Permitted point sources include EWSU's eight CSO discharges to lower Pigeon Creek, five industrial dischargers, and six municipal wastewater treatment plants (WWTP). The CSOs are addressed below under the context of the SRCER. The five industrial discharges appear to be minor contributors of pollutants to Pigeon Creek, with generally good compliance records. In general, the municipal WWTPs in the watershed do not have acceptable performance records and require expansion, upgrading, and/or additional operator training. Three municipal WWTPs are currently being upgraded, but more should be studied for possible upgrade or expansion.

- The Chandler WWTP has a history of poor compliance, but is currently being upgraded, so pollutant discharges from this point source may be reduced in the future.
- The Haubstadt WWTP also had a history of poor compliance. We verified this with our sampling program. This WWTP is also being upgraded to reduce wet weather overflows and improve effluent quality.
- The Fort Branch WWTP also has noncompliance reports to its records. We measured high coliform bacteria concentrations, high nitrates, and supersaturated dissolved oxygen conditions downsteam of this facility. No plans for expansion or upgrading have been located for this WWTP.
- The Elberfeld WWTP has numerous noncompliance reports in the EPA's Permit Compliance System database. It is currently being expanded.

Major nonpoint sources of pollutants to the watershed are row crop agriculture, mined lands, and urban runoff. Cropland area in the watershed has been reasonably constant since 1997. Watershed wide, conservation tillage systems were used on 25% of cropland in 1997, 16% of cropland in 1998, and 33% of cropland in 2000. Data on the conservation tillage in the watersheds are insufficient to statistically demonstrate trends. In the year 2000, the Warrick County portion of the study area had the highest rate of conservation tillage adoption, with 51% of its cropland in some type of conservation tillage.

We prepared a model of agricultural nonpoint source sediment and phosphorus pollution in the Pigeon Creek watershed using the best available data. Exhibits 21 and 22 present an overall picture of the spatial loadings of these pollutants. The details of our estimates are tabulated below.

According to our land use data, soils information, and nonpoint source models, subwatersheds 6, 18, 20, 22, 23, 24, 26 and 26 are the priority areas for investing in soil erosion controls. These subwatersheds contain Fairpoint and Alford soils that appear to be tilled. Undoudtedly, some of these areas have since been set aside under the Conservation Reserve Program, but we do not have a theme in the GIS to compensate the model for such practices. Regardless, tillage of the Fairpoint or Alford soil associations will result in very high soil loss rates and special efforts to mitigate these areas will reap significant benefits.

SUBWATERSHED ANNUAL SEDIMENT YIELD (tons)

Subwatershed	Annual Yield	Area (acres)	Unit Areal Loading (tons/acre)
1. Locust Creek Lower	294	6,101	0.05
2. Locust Creek Headwaters	501	6,497	0.08
3. Kleymeyer Park	9	4,176	0.00
4. Harper Ditch	118	6,544	0.02
5. Crawford Brandeis Ditch	321	5,903	0.05
6. Weinsheimer Ditch	1,559	9,103	0.17
7. Barnes Ditch	759	13,216	0.06
8. Dennis Wagner Ditch	236	4,231	0.06
9. Firlick Creek	205	4,171	0.05
10. Stubbs Fruedenberg Ditch	194	3,911	0.05
11. Schlensker Ditch	377	4,622	0.08
12. Little Pigeon Creek	308	11,209	0.03
13. Unnamed Trib to Bluegrass	370	5,247	0.07
14. Bluegrass Creek Headwaters	448	6,190	0.07
15. Clear Branch	939	14,582	0.06
16. Squaw Creek	846	8,543	0.10
17. Big Creek - Little Creek	878	10,524	0.08
18. Big Creek Headwaters	1,623	11,604	0.14
19. Big Creek – Wye	465	7,117	0.07
20. Smith Fork Headwaters	1,148	14,573	0.08
21. Smith Fork - Halfmoon Cr	832	10,672	0.08
22. Snake Run	1,301	14,449	0.09
23. Hurricane Ditch Creek	2,327	10,420	0.22
24. West Fork Creek	6,712	19,064	0.35
25. Clear Fork Ditch	5,299	11,359	0.47
26. Sand Creek - Muddy Fork	1,643	11,200	0.15
TOTAL	**29,712**	**235,228**	

SUBWATERSHED ANNUAL PHOSPHORUS LOADING (kg)

Subwatershed	Load (kg)	Area (acres)	Unit Areal Loading (kg/acre)
1. Locust Creek Lower	388	6,101	0.06
2. Locust Creek Headwaters	662	6,497	0.10
3. Kleymeyer Park	12	4,176	0.00
4. Harper Ditch	156	6,544	0.02
5. Crawford Brandeis Ditch	424	5,903	0.07
6. Weinsheimer Ditch	2,058	9,103	0.23
7. Barnes Ditch	1,002	13,216	0.08
8. Dennis Wagner Ditch	312	4,231	0.07
9. Firlick Creek	271	4,171	0.06
10. Stubbs Fruedenberg Ditch	255	3,911	0.07
11. Schlensker Ditch	498	4,622	0.11
12. Little Pigeon Creek	406	11,209	0.04
13. Unnamed Trib to Bluegrass Cr	488	5,247	0.09
14. Bluegrass Creek Headwaters	591	6,190	0.10
15. Clear Branch	1,239	14,582	0.08
16. Squaw Creek	1,117	8,543	0.13
17. Big Creek - Little Creek	1,159	10,524	0.11
18. Big Creek Headwaters	2,142	11,604	0.18
19. Big Creek – Wye	614	7,117	0.09
20. Smith Fork Headwaters	1,515	14,573	0.10
21. Smith Fork - Halfmoon Creek	1,098	10,672	0.10
22. Snake Run	1,718	14,449	0.12
23. Hurricane Ditch Creek	3,071	10,420	0.29
24. West Fork Creek	8,860	19,064	0.46
25. Clear Fork Ditch	6,994	11,359	0.62
26. Sand Creek - Muddy Fork Ditch	2,168	11,200	0.19
TOTAL	**39,218**	**235,228**	

AGRICULTURAL NONPOINT SOURCE RECOMMENDATIONS

Best management practices, or BMPs, are restrictions, structures or practices that mitigate the adverse anthropogenic effects of runoff quality and/or quantity. There is a broad range of BMPs for agricultural lands. Chapter 6 and Appendix D discuss many of these. For the lands in the study area where corn and soybean production is the dominant use, some of the most effective BMPs include conservation tillage, conservation buffers and nutrient management. All of these are recommended.

As indicated earlier, subwatersheds 6, 18, 20, 22, 23, 24, 25 and 26 are the priority areas for investing in soil erosion controls. These subwatersheds contain Fairpoint and Alford soils that appear to be tilled. Tillage of the Fairpoint or Alford soil associations will result in very high soil loss rates and special efforts to mitigate these areas will have significant benefits.

We strongly recommend stream corridor restoration efforts in nearly all subwatersheds. Corridor restoration is a complex endeavor that begins with the recognition that human-induced changes that began nearly two centuries ago have damaged the structure and function of the ecosystem and prevent the recovery of the watershed to a sustainable condition. A restoration effort of this magnitude will require institutional and public support at all levels to succeed. To facilitate corridor restoration, we recommend the following initial steps:

1. Revitalization of a stakeholder steering committee to focus and direct the effort
2. Preparation of a restoration feasibility study and master plan
3. Consideration of local ordinances requiring stream conservation buffers. Appendix E is a model ordinance for stream buffers. Enacting such as ordinance is a significant step towards sustainable watershed management.

A crop nutrient management plan can increase the efficiency of crop fertilizer use while reducing nutrient losses to streams and lakes. All Indiana counties have extension agents available to provide technical assistance for developing nutrient management plans. Preparation of nutrient management plans for the entire study area will cost approximately $1,000,000. While nutrient management plans are appropriate for most, if not all, farms, we recommend priority be given to subwatersheds 2, 6, 8, 16, 23, 24, 25 and 26. The farms closest to the streams in these subwatersheds should be given priority for nutrient management resources. The cost of preparation of nutrient management plans in these eight subwatersheds is approximately $400,000.

SRCER

We monitored Evansville's combined sewer system tributary to Pigeon Creek and examined available operational records. We also monitored CSO events for eight months. From the water quality data, the waterway is most affected by the discharges of *E. coli* bacteria. That water quality standard is regularly exceeded during wet weather both within and upstream of the CSO discharge area. There is little evidence that other water quality standards are routinely violated due to CSO discharges.

The inflow/infiltration monitoring program should be expanded in the EWSU's combined sewer system. Since more overflows appear to occur in areas with high concentrations of commercial/industrial customers it is recommended that inspection of all commercial and industrial structures be undertaken to identify any additional sources of inflow and infiltration to the sewer system. Existing flow monitoring efforts should also be greatly expanded to confirm the capacities of major sanitary sewers and to verify the results of earlier capacity analyses.

In view of the fact that overflows continue to be significant and are perhaps causing deterioration of Pigeon Creek, Evansville should continue to investigate the feasibility of providing in-line storage in 11 subsystems and detention/retention basins at various sites. A gate control system, which would control the non-automated CSOs to Pigeon Creek and the Ohio River, would allow the storage of combined sewerage in the interceptors tributary to the diversions. This gate control system could provide about 154,5000 cubic feet (11.6 MG) of storage. A study to investigate the feasibility of such a system and the condition of the sewers at the storage sites is warranted and should be implemented.

Evaluation of a runoff control program to store and control runoff before it enters the combined system is also recommended. The feasibility and effectiveness of this alterative requires development of a system model, scheduled for completion as part of the long-term CSO control plan.

PIGEON CREEK
WATERSHED DIAGNOSTIC STUDY

TABLE OF CONTENTS

CHAPTER PAGE

EXECUTIVE SUMMARY ES-1

FOREWORD 1

1.0 INTRODUCTION 3
 1.1 OBJECTIVES 3
 1.2 LOCATION 3
 1.3 ENVIRONMENTAL SETTING 3
 1.4 POPULATION 4
 1.5 WATERSHED SIZE AND TOPOGRAPHY 5
 1.6 LEGAL DRAINS 7
 1.7 CLIMATE 7
 1.8 GEOLOGY AND SOILS 9
 1.9 AGRICULTURAL ECONOMY 9
2.0 WATERSHED CHARACTERISTICS 13
 2.1 LAND USE AND COVER 13
 2.2 WETLANDS 14
 2.3 DEMOGRAPHICS AND DEVELOPMENT TRENDS 15
 2.4 HISTORICAL WATER QUALITY 16
 2.5 FISH 17
 2.6 THREATENED AND ENDANGERED SPECIES 19
3.0 WATERSHED BIOASSESSMENT 22
 3.1 CHEMICAL QUALITY 22
 3.2 PHYSICAL HABITAT 28
 3.3 MACROINVERTEBRATE COMMUNITIES 35
 3.4 SUMMARY OF TRIBUTARY HEALTH 41
4.0 POLLUTION SOURCES 43
 4.1 POINT SOURCES 43
 4.2 NONPOINT SOURCES 47
5.0 STREAM REACH CHARACTERIZATION AND EVALUATION 62

5.1 CHARACTERIZATION OF THE COMBINED SEWER SYSTEM.......62
5.2 EVALUATION OF THE NINE MINIMUM CONTROLS......................75
5.3 CSO MONITORING..89
5.4 MUNICIPALITIES, SENSITIVE AREAS AND RECREATIONAL FACILITIES..102
5.5 CONCLUSIONS AND RECOMMENDATIONS..................................103
6.0 WATERSHED MANAGEMENT PLAN...110
6.1 BIOTIC AND ABIOTIC RELATIONSHIPS..110
6.2 SUBBASIN RECOMMENDATIONS..114
6.3 AGRICULTURAL BEST MANAGEMENT PRACTICES...................126
6.4 URBAN BEST MANAGEMENT PRACTICES....................................131
6.5 CONSTRUCTED WETLANDS...135
6.6 FUNDING SOURCES...137
7.0 CONCLUSIONS AND RECOMMENDATIONS......................................142
7.1 PROTECTION OF SELECTED AREAS..142
7.2 RESTORATION OF STREAM CORRIDOR..142
7.3 HIGHLY ERODIBLE LANDS...144
7.4 POINT SOURCE CONTROLS..144

REFERENCES

EXHIBITS

APPENDICES

LIST OF EXHIBITS

Exhibit 1	Location Map
Exhibit 2	CSO Service Area
Exhibit 3	Elevation Map
Exhibit 4	Soil Associations Map
Exhibit 5	Land Use Map
Exhibit 6	Land Use/Land Cover in the Pigeon Creek Watershed
Exhibit 7	Historic Water Quality Data
Exhibit 8	Threatened and Endangered Species and Natural Areas in the Study Area
Exhibit 9	Monitoring Sites
Exhibit 10	Subwatershed Boundaries
Exhibit 11	Exceedances of Coliform Bacteria Standard at the Monitoring Sites
Exhibit 12	Total Phosphorus Concentrations at the Monitoring Sites
Exhibit 13	Total Suspended Solids at the Monitoring Sites
Exhibit 14	QHEI Scores at the Monitoring Sites
Exhibit 15	Silt Cover at the Monitoring Sites
Exhibit 16	Family Biotic Indices at the Monitoring Sites
Exhibit 17	Relative Biotic Integrity of the Monitoring Sites
Exhibit 18	Ranking of Monitoring Sites and Subwatersheds by Ecological Health Indicators
Exhibit 19	Pollutant Point Sources Map
Exhibit 20	NPDES Permitted Facilities in the Pigeon Creek Watershed
Exhibit 21	Nonpoint Sediment Loadings to Pigeon Creek
Exhibit 22	Nonpoint Phosphorus Loadings to Pigeon Creek
Exhibit 23	Characteristics of CSO Service Areas Discharged to Pigeon Creek
Exhibit 24	Combined Sewer Overflow (cfs) at Diamond Avenue
Exhibit 25	Combined Sewer Overflow (cfs) at Oakhill Avenue
Exhibit 26	Combined Sewer Overflow (cfs) at Maryland Avenue
Exhibit 27	Suspended Solids Concentrations for All Storm Events
Exhibit 28	BOD Concentrations for All Storm Events
Exhibit 29	*E. Coli* Concentrations for All Storm Events
Exhibit 30	Phosphorus Concentrations for All Storm Events
Exhibit 31	Total Kjeldahl Nitrogen Concentrations for All Storm Events
Exhibit 32	Ammonia Nitrogen Concentrations for All Storm Events
Exhibit 33	Arsenic Concentrations for All Storm Events
Exhibit 34	Zinc Concentrations for All Storm Events
Exhibit 35	Chromium Concentrations for All Storm Events

Exhibit 36 Copper Concentrations for All Storm Events
Exhibit 37 Lead Concentrations for All Storm Events
Exhibit 38 Nickel Concentrations for All Storm Events
Exhibit 39 Phosphorus Concentrations Over Stream Length
Exhibit 40 BOD Concentrations Over Stream Length
Exhibit 41 Suspended Solids Concentrations Over Stream Length
Exhibit 42 *E. Coli* Concentrations Over Stream Length
Exhibit 43 Ammonia Nitrogen Concentrations Over Stream Length
Exhibit 44 Total Kjeldahl Nitrogen Concentrations Over Stream Length
Exhibit 45 Nitrate Nitrogen Concentrations Over Stream Length
Exhibit 46 Biotic-Abiotic Correlation Matrix
Exhibit 47 Subwatershed Recommendations
Exhibit 48 Cable Dam Generic Plan, Profile, Section and Details

LIST OF TABLES

Table 1	Pigeon Creek Subwatersheds
Table 2	Watershed Climate Data (1961-1990) taken at Evansville Airport
Table 3	Gibson County Agricultural Statistics
Table 4	Vanderburgh County Agricultural Statistics
Table 5	Warrick County Agricultural Statistics
Table 6	Land Use in the Pigeon Creek Watershed
Table 7	Crop and Livestock Statistics for Warrick, Gibson and Vanderburgh Counties
Table 8	Wetlands in the Study Area
Table 9	Non-Agricultural Employment in the Watershed
Table 10	Fishes Historically Present in the Pigeon Creek Watershed
Table 11	Threatened and Endangered Species in the Study Area
Table 12	Natural Areas in the Study Area
Table 13	Sites With Documented DO Supersaturation or Sites Not Meeting DO Standard
Table 14	Sites With Documented Dry Weather Exceedances of the *E. Coli* Standard
Table 15	Discharge Measurements
Table 16	Qualitative Habitat Evaluation Indices (August 1999)
Table 17	Qualitative Habitat Evaluation Indices (May 2000)
Table 18	Substrate Quality Scores (August 1999)
Table 19	Substrate Quality Scores (May 1999)
Table 20	Macroinvertebrate Matrix Scores (August 1999)
Table 21	Macroinvertebrate Matrix Scores (May 2000)
Table 22	Relative Tributary Biotic Integrity
Table 23	NPDES Discharges to Pigeon Creek
Table 24	Cropland Acreage and Tillage Systems, 1997 – 2000
Table 25	Residue Cover Classes for each Tillage System in 2000
Table 26	Crop Acreage by Tillage System in 2000
Table 27	Slope of Lands Planted to Various Crops
Table 28	Soil Erodibility “K” Values
Table 29	Topographic Factors
Table 30	C Values for Land Uses in the Watershed
Table 31	Subwatershed Annual Sediment Yield
Table 32	Subwatershed Annual Phosphorus Yield
Table 33	Average Inflows To Eastside And Westside WWTPs During Wet Weather

Table 34	Overflow Events at Oakhill CSO #011
Table 35	Overflow Events at Maryland CSO #012
Table 36	Overflow Events at Diamond CSO #025
Table 37	CSO Volume Summary Statistics
Table 38	Combined Sewer Overflows And Rainfall Events
Table 39	*E. Coli* Concentrations During Storm Events
Table 40	Selection of Representative Bioassessment Sites
Table 41	Pearson's Product-Moment Correlation Coefficients
Table 42	Operating Costs ($/acre) for Conventional Tillage Versus No-till
Table 43	Estimated Costs for Development of Nutrient Management Plans
Table 44	Constructed Wetland Pollutant Removal Efficiency

APPENDICES

Appendix A	Institutional Resources Assessment
Appendix B	Laboratory Analytical Reports
Appendix C	Bioassessment Field Notes
Appendix D	Agricultural Best Management Practices
Appendix E	Model Riparian Buffer Ordinance

LIST OF ACRONYMS

BMP	Best Management Practice
BOD	Biochemical Oxygen Demand
CRP	Conservation Reserve Program
CSO	Combined Sewage Overflow
CSS	Combined Sewage System
DNR	Department of Natural Resources
DO	Dissolved Oxygen
EMC	Environmental Management Corporation
EPA	United States Environmental Protection Agency
EWSU	Evansville Water and Sewer Utility
FBI	Family Biotic Index
GIS	Geographic Information System
HUC	Hydrologic Unit Code
IDEM	Indiana Department of Environmental Management
ISDH	Indiana State Department of Health
LARE	Lake and River Enhancement Program
LTCP	Long Term Control Plan
NPDES	National Pollutant Discharge Elimination System
NPS	Nonpoint Source Pollution
PCS	Permit Compliance System
QHEI	Qualitative Habitat Evaluation Index
RBP	Rapid Bioassessment Protocol
SRCER	Stream Reach Characterization and Evaluation Report
STORET	Storage and Retrieval Database System
TKN	Total Kjeldahl Nitrogen
UAA	Use Attainability Analysis
USLE	Universal Soil Loss Equation
WWTP	Wastewater Treatment Plant

FOREWORD

Authorization

This diagnostic study of the Pigeon Creek watershed is authorized by contracts between the Evansville Water and Sewer Utility and Harza Engineering Company, Inc. dated June 4, 1999, and Four Rivers Resource Conservation and Development Area, Inc. and Harza dated June 11, 1999, as amended August 3, 1999.

Scope

The scope of the diagnostic study included collection and analysis of secondary and primary data. The geographic limits of the study include Pigeon Creek and McFadden Creek, both parts of the Pigeon-Highland watershed, USGS Hydrologic Cataloging Unit 05140202. Principal activities are summarized below.

1. Summarize Historical Information. Discussion of historical data on land use, soils, geology, water use and quality, recreation, wildlife, stakeholder and population data.
2. Map Current Watershed Conditions, including soils, highly erodible land, wetlands, significant natural areas, threatened or endangered species, critical habitat, land use/land cover, NPDES discharge locations, and other watershed information.
3. Evaluate Water Quality, Biology and Habitat. Water quality, Rapid Bioassessment Protocol II, and Qualitative Habitat Evaluation Index data were collected in six tributary sites.
4. Watershed Nonpoint Source Pollution. Sediment and nutrient loading for tributary watersheds were estimated.
5. CSO Monitoring and Evaluation. This study includes a Stream Reach Characterization Evaluation per the guidelines of the Indiana Department of Environmental Management (IDEM).
6. Watershed Plan, intended to identify and rank tributary watersheds for land treatment and other projects to mitigate nonpoint source pollution.
7. Recommend Institutional Initiatives.

While all of these activites were performed in the Pigeon Creek watershed, studies on McFadden Creek were limited to a bioassessment (activity 3).

Organization

This report is organized as three volumes. Volume 1 is the main report and addresses the Pigeon Creek watershed. Volume 2 addresses the McFadden Creek watershed. Volume 3 contains all appendices.

Acknowledgments

Financing for this study was provided by the Evansville Water and Sewer Utility (EWSU), the State of Indiana's Lake and River Enhancement (LARE) Program, administered by the DNR's Division of Soil Conservation, and by the IDEM Office of Water Management. Grants from the LARE Program and IDEM Watershed Management Section were administered by the Four Rivers Resource Conservation and Development Area, Inc.

Harza is especially grateful for the assistance provided by Mr. Joe Potts of EMC, on behalf of the EWSU, in the monitoring of combined sewer overflows (CSOs) and wet weather events. We also appreciate the assistance of Ms. Amy Steeples of the IDNR in orchestrating the myriad of activities involved in developing the information base for a watershed plan of this scale. Many others assisted this effort by making data available to us, including Mr. Rick Obenshein, Pigeon Creek Watershed Coordinator; Mr. Chuck Bell of IDEM; Ms. Carrie Parmenter of Vanderburgh County SWCD; Ms. Gwen White of the IDNR; and Mr. Kenneth J. Eck of Purdue University Department of Agronomy. IDEM Section 319 Project Managers for this study were Mr. Neil Schoeder, Ms. Heather Rippey and Ms. Amy Reeves.

The Harza study team included Wade Moore, Erich Brandstetter, Edward Belmonte, Richard Persaud, Hammad Hussain, Beth Padera and Joyce Coffee. David Pott was Harza's project manager. Subcontractors included ADS Environmental Services, Inc. of Indianapolis and Central States Analytical, of Evansville.

1.0 INTRODUCTION

This chapter of the diagnostic report describes the study objectives, provides general information and details historical data for the study area.

1.1 OBJECTIVES

The Pigeon Creek Watershed Diagnostic Study has two goals. First, the IDEM has required the Evansville Water and Sewer Utility to prepare a Stream Reach Characterization and Evaluation Report that addresses combined sewer overflows (CSOs) in its service area drained by Pigeon Creek. Second, areas of the Pigeon Creek watershed upstream of Evansville are subjected to nonpoint source pollution (NPS) from agricultural, mining and other land uses detrimental to stream health, and the Soil and Water Conservation Districts (SWCD) of Vanderburgh, Gibson and Warrick Counties have commissioned a diagnostic study of NPS in the watershed. The overall objectives of this diagnostic study are to identify sources of pollution in the Pigeon Creek watershed study area, and, to recommend land management projects, institutional reforms, and potential financing for pollution mitigation.

1.2 LOCATION

The Pigeon Creek watershed lies in parts of Vanderburgh, Warrick, Gibson and Pike Counties in southwestern Indiana. Exhibit 1 is a location map. The CSO service area is limited to parts of Vanderburgh County (Exhibit 2).

1.3 ENVIRONMENTAL SETTING

Pigeon Creek enters the Ohio River at mile point 792.9 after draining 375 square miles of southwestern Indiana. The drainages of both Pigeon Creek and McFadden Creek are largely rural, and contain a variety of land uses and cover types. Land use/land cover types in the watershed include forests, water and wetlands, prairies, residential and commercial urban areas, industrial and ruderal areas, active and reclaimed mined lands, and agriculture. These habitats provide for an abundant and diverse fauna. Principal crops include wheat, corn and soybeans. Large tracts of coal mined lands are on the eastern sides of the watershed, in Warrick and Gibson Counties. There are also oils fields in parts of Gibson County and Posey County.

Stream habitat in the mainstem is generally poor. This poor habitat is attributable to channelization for agricultural development and navigation. In 1853 the Wabash and Erie Canal extension was completed through Evansville, forming, at that time, the longest man-made waterway in the Western Hemisphere. The Wabash and Erie Canal crosses the watershed boundary at Francisco. In 1860, after only a few years of use, the southern part of the canal was abandoned, leaving Pigeon Creek without much of its natural meanders, pools or riffles.

Today, Pigeon Creek is deemed by the Natural Resources Commission to be a navigable waterway from its mouth at the Ohio River upstream 15.8 river miles. Locust Creek, which enters Pigeon Creek one-half mile downstream of the Illinois Central Gulf Railroad Bridge, is also a navigable waterway for its first 1.5 miles. Portions of Little Pigeon Creek, Clear Creek and Baker Creek are also considered navigable waterways.

1.4 POPULATION

The City of Evansville was founded on March 27,1812 by Colonel Hugh McGary. On January 7, 1818, Vanderburgh County was created. In 1837, the first cabinet-making shop and steam-powered sawmill opened, in anticipation of the completion of the Wabash and Erie Canal. By 1900, Evansville had over 300 iron, steel and woodworking companies and had become a center for furniture manufacturing. Automobile production and refrigerator manufacturing dominated the local economy by the mid 1920's. The effects of the Great Depression were lessened with the discovery of oil in the area in the early 1930's and the gearing up for World War II. In 1942, the Evansville Ship Yard was established and factories were converted to build airplanes for the war effort. After the war the demand for automobiles, household appliances and farm equipment helped to maintain employment and create a network of industrial suppliers and service shops.

During the 1950's, many auto, refrigerator and stove manufacturers closed their doors or were sold, while other industrial concerns relocated to Evansville. Currently, Evansville is home to a large number of plastics related companies. Other notable companies are involved in pharmaceutical, aluminum sheet, food products, and home appliance production.

The Evansville IN-Henderson KY Metropolitan Statistical Area (MSA) consists of Vanderburgh, Posey, Warrick counties in IN and Henderson County, KY. The Evansville MSA ranks 114th in population nationwide. As a city, Evansville ranks 130th in the nation and is the 3rd largest city in the state of Indiana. The MSA has 120,962 households, while the city has 55,144 households. Evansville is a regional economic center, as evidenced by the location of three major hospitals, two full service universities and a vibrant retail and banking community.

Evansville has a 1990 population of 126,272 person residing in 53,058 households. Other communities in the watershed include Chandler, Fort Branch, Haubstadt, and portions of Owensville and Princeton.

Evansville supplies its residents with drinking water from collection and treatment of surface water and ground water. Water service is provided to Evansville by the City's Water and Sewer Utility Department. Sources include the Ohio River and an auxiliary deep well. Filtration system capacity is 60.0 million gallons per day (mgd) to meet current peak demands of 35 mgd. The Evansville Water & Sewer Utility also operates two sewage treatment facilities with a capacity 38.6 mgd. Average daily wastewater flows are 28 mgd. EWSU uses a land application system to dispose of its sludge. While EWSU discharges treated wastewater to the Ohio River, many of the smaller upstream communities, as well as some industrial facilities, are permitted to discharge treated wastewater to Pigeon Creek.

1.5 WATERSHED SIZE AND TOPOGRAPHY

The Pigeon Creek watershed is 235,226 acres (95,195 ha, 367.5 mi^2) in area. The greatest length of the watershed is 29 miles (46 km) and greatest width is 24 mi (39 km). Land elevation in the study area ranges from about 340 feet at the Ohio River to 550 feet in some upper reaches of the watershed (Exhibit 3). Land is generally level in the Ohio River and Pigeon Creek bottom lands and terraces. While slopes are typically gentle, short lengths of slope may be up to 50% in certain upland areas.

The United States is divided and sub-divided into successively smaller hydrologic units. Each hydrologic unit is identified by a unique hydrologic unit code (HUC) consisting of two to fourteen digits based on the multiple levels of classification in the hydrologic unit system. The fourteen-digit level of classification was available for the study area and supplied to Harza by Rick Obenshein, the watershed coordinator. There are 26 subwatersheds in the Pigeon Creek watershed, and these are the spatial units of diagnostic study in this report (Table 1). These subwatersheds are delineated in Exhibit 1.

Table 1

PIGEON CREEK SUBWATERSHEDS

Number	HUC	Name	Acres	Hectares
1	05140202040120	Pigeon Creek-Locust Creek (lower)	6,099	2,468
2	05140202040110	Locust Creek-Headwaters	6,495	2,629
3	05140202040100	Pigeon Creek-Kleymeyer Park	4,175	1,690
4	05140202040080	Pigeon Creek-Harper Ditch	6,543	2,648
5	05140202040010	Pigeon Creek-Crawford Brandeis Ditch	5,902	2,388
6	05140202030060	Weinsheimer Ditch	9,100	3,683
7	05140202030070	Pigeon Creek-Barnes Ditch	13,213	5,347
8	05140202040060	Bluegrass Creek-Dennis Wagner Ditch	4,230	1,712
9	05140202040070	Bluegrass Creek-Firlick Creek	4,170	1,687
10	05140202040040	Bluegrass Creek-Stubbs Fruedenberg Ditch	3,910	1,582
11	05140202040050	Schlensker Ditch	4,621	1,870
12	05140202040090	Little Pigeon Creek	11,206	4,535
13	05140202040030	Unnamed Tributary (Blue Grass Creek)	5,245	2,123
14	05140202040020	Bluegrass Creek-Headwaters	6,188	2,504
15	05140202030040	Pigeon Creek-Clear Branch	14,578	5,900
16	05140202030050	Squaw Creek	8,541	3,456
17	05140202030020	Big Creek-Little Creek/Plum Branch	10,521	4,258
18	05140202030010	Big Creek-Headwaters (Warrick)	11,600	4,695
19	05140202030030	Big Creek-Wye In RR (Pigeon Creek)	7,115	2,879
20	05140202020060	Smith Fork-Headwaters	14,569	5,896
21	05140202020070	Smith Fork-Halfmoon Creek	10,669	4,318
22	05140202020050	Pigeon Creek-Snake Run	14,445	5,846
23	05140202020030	Hurricane Creek Ditch	10,417	4,216
24	05140202020040	West Fork Creek	19,060	7,713
25	05140202020020	Pigeon Creek-Clear Fork Ditch	11,356	4,596
26	05140202020010	Sand Creek-Muddy Fork Ditch	11,197	4,531

1.6 LEGAL DRAINS

The Indiana statute at IC 36-9-27 contains the County Drainage Code. This law authorizes county drainage boards to regulate certain drains. The intent of this law is to increase the hydraulic efficiency of waterways and control upstream ponding and flooding. The county surveyor is the technical authority on the construction, reconstruction, and maintenance of all regulated drains or proposed regulated drains in the county. The County Drainage Code requires the county surveyor to classify regulated drains in the county as:

1. Drains in need of reconstruction;
2. Drains in need of periodic maintenance; or
3. Drains that should be vacated.

The county drainage boards across the state fund reconstruction and maintenance of regulated drains. Among the board's duties, as defined in the statute, is the reconstruction of regulated drains that do not properly function and may require erosion control or grade stabilization structures. An example project undertaken under this authority is the Gibson County Drainage Board's reshaping of nearly six miles of Pigeon Creek and West Fork in 2000. This project, while justified on the basis of flood control, exemplifies continued single objective management of water courses in the watershed and abuse of ecological consequences.

The County Drainage Code also offers opportunities for financing of watershed projects. We believe this regulatory vehicle is considerably underutilized in the state for environmental change due to the traditional use of these funds for drainage purposes only.

1.7 CLIMATE

While Indiana has warm summers and cold winters, temperatures fluctuates both daily and seasonally as surges of polar air move southward or tropical air masses move northward. Temperature fluctuations are more common in winter than in summer. Severe storms and tornadoes are more frequent in the spring months. Temperature and precipitation data for the area are presented below. Spring is generally the wettest season in southwestern Indiana. The length of the growing season ranges from 166 to 233 days.

Table 2

WATERSHED CLIMATE DATA (1961-1990) TAKEN AT EVANSVILLE AIRPORT (Source: Midwestern Regional Climate Center, Champaign, IL)

	Temperatures			Precipitation		
Month	Maximum	Minimum	Mean	Mean	High	Low
January	38.9	21.2	30.1	2.66	14.78	0.51
February	43.7	25	34.4	3.12	7.26	0.27
March	55.9	35.7	45.8	4.71	12.84	0.01
April	67.4	45	56.2	4.02	11.83	0.4
May	76.9	54.2	65.5	4.75	13.51	0.59
June	86.2	63.3	74.8	3.49	11.44	0.38
July	89.1	67.5	78.4	4.04	10.32	0.18
August	87.2	64.9	76.1	3.11	8.43	0.13
September	80.7	57.6	69.2	2.97	9.89	0.25
October	69.6	44.7	57.2	2.87	11.19	0.01
November	55.9	36.5	46.2	3.73	9.24	0.2
December	43.6	26.7	35.2	3.67	8.23	0.56
Annum	66.3	45.2	55.8	43.14	64	25.55

1.8 GEOLOGY AND SOILS

The study area is in unglaciated terrain of the Wabash Lowland Region. The watershed is nearly entirely underlain by the McLeansboro Group Patoka and Shelburn bedrock formations of Pennsylvanian age. The outcrop belt of the McLeansboro Group extends from western Warrick County northward to southwestern Vermillion County. The maximum thickness of 770 feet (235 m) is reached in the Mumford Hills in northern Posey County. Shale and sandstone make up more than 90 percent of this sequence, but minor amounts of siltstone, limestone, clay, and coal are present (Wier 1961, 1965).

Soil associations in the study area are mapped on Exhibit 4. Most soils are silt loams that range from zero to 18% slopes. Within the Pigeon Creek watershed, there are 64,300 acres of highly erodible land, much of which is eroding well above “T”, the tolerable limit.

1.9 AGRICULTURAL ECONOMY

The study area depends upon agriculture for much of its well-being. Recent agricultural statistics show local agricultural trends following much of the State and the nation, that is, a trend towards fewer, but larger farms with greater returns. Under this trend, farms offer diminished employment opportunities and greater efficiency.

Table 3

GIBSON COUNTY AGRICULTURAL STATISTICS
(Source: Stats Indiana)

Statistic	1997	1992	1987
Farms (number)	579	720	846
Land in farms (acres)	232,839	241,049	248,054
Land in farms - average size of farm (acres)	402	335	293
Estimated market value of land and buildings average per farm	$744,849	$497,443	$351,981
Farms by size: 1 to 9 acres	46	43	68
Farms by size: 10 to 49 acres	115	167	183
Farms by size: 50 to 179 acres	149	204	232
Farms by size: 180 to 499 acres	122	149	205
Farms by size: 500 to 999 acres	73	90	102
Farms by size: 1,000 acres or more	74	67	56
Total cropland (farms)	541	663	780
Total cropland (acres)	211,810	218,182	218,618
Total harvested cropland (acres)	198,806	202,153	178,420
Market value of agricultural products sold ($1,000)	69,056	65,951	54,942
Market value of agricultural products sold, average per farm	$119,268	$91,599	$64,944
Market value of ag products sold - livestock, poultry, and their products ($1,000)	12,933	13,537	18,965
Net cash return from ag sales, average per farm	$28,199	$27,732	$12,447
Operators by principal occupation: Farming	314	414	493
Operators by principal occupation: Other	265	306	353
Livestock and poultry: Cattle and calves inventory (farms)	151	193	249
Livestock and poultry: Cattle and calves inventory (number)	6,620	7,420	9,441
Beef cows (number)	1,870	2,379	3,046
Milk cows (number)	963	1,077	707
Hogs and pigs inventory (number)	38,267	40,612	42,504

Table 4

VANDERBURGH COUNTY AGRICULTURAL STATISTICS
(Source: Stats Indiana)

Statistic	1997	1992	1987
Farms (number)	271	305	378
Land in farms (acres)	72,112	80,958	85,852
Land in farms - average size of farm (acres)	266	265	227
Estimated market value of land and buildings average per farm	$661,549	$458,642	$396,690
Farms by size: 1 to 9 acres	31	26	40
Farms by size: 10 to 49 acres	68	91	103
Farms by size: 50 to 179 acres	76	75	105
Farms by size: 180 to 499 acres	58	68	85
Farms by size: 500 to 999 acres	23	30	36
Farms by size: 1,000 acres or more	15	15	9
Total cropland (farms)	259	285	354
Total cropland (acres)	66,532	74,580	78,628
Total harvested cropland (acres)	64,540	70,536	65,911
Market value of agricultural products sold ($1000)	20,875	22,279	17,993
Market value of agricultural products sold average per farm	$77,030	$73,044	$47,601
Market value of ag products sold - livestock, poultry and their products ($1,000)	2,323	2,862	3,095
Net cash return from ag sales, average per farm	$16,468	$21,241	$9,793
Operators by principal occupation: Farming	130	174	192
Operators by principal occupation: Other	141	131	186
Livestock and poultry: Cattle and calves inventory (farms)	57	87	105
Livestock and poultry: Cattle and calves inventory (number)	1,808	2,639	2,862
Beef cows (number)	364	714	561
Milk cows (number)	478	534	649
Cattle and calves sold (number)	723	1,590	1,763
Hogs and pigs inventory (number)	3,804	6,161	4,041

Table 5

WARRICK COUNTY AGRICULTURAL STATISTICS
(Source: Stats Indiana)

Statistic	1997	1992	1987
Farms (number)	356	392	432
Land in farms (acres)	98,549	96,219	99,944
Average size of farm (acres)	277	245	231
Estimated market value of land and buildings average per farm	$494,724	$353,196	$274,870
Farms by size: 1 to 9 acres	23	22	27
Farms by size: 10 to 49 acres	79	100	110
Farms by size: 50 to 179 acres	125	136	155
Farms by size: 180 to 499 acres	72	76	79
Farms by size: 500 to 999 acres	36	37	39
Farms by size: 1,000 acres or more	21	21	22
Total cropland (farms)	323	365	396
Total cropland (acres)	80,901	80,728	83,998
Total harvested cropland (acres)	73,939	71,863	64,228
Market value of agricultural products sold ($1,000)	23,671	19,773	16,135
Market value of agricultural products sold average per farm	$66,491	$50,442	$37,349
Market value of ag products sold – livestock, poultry and their products ($1,000)	4,519	4,261	5,095
Net cash return from ag sales, average per farm	$10,358	$6,687	$4358
Operators by principal occupation: Farming	164	182	200
Operators by principal occupation: Other	192	210	232
Livestock and poultry: Cattle and calves inventory (farms)	144	142	186
Livestock and poultry: Cattle and calves inventory (number)	4,630	4,647	5,854
Beef cows (number)	1,596	1,896	1,984
Milk cows (number)	586	417	746
Cattle and calves sold (number)	1,787	1,781	3,025
Hogs and pigs inventory (number)	11,829	15,762	13,397

2.0 WATERSHED CHARACTERISTICS

This chapter characterizes the watershed's land use and cover, wetland types and prevalence, demographics, and historical data on water quality, wildlife and institutions.

2.1 LAND USE AND COVER

Our land use/land cover data were derived from the Indiana GAP Project (1998). The interagency project, led by the U.S. Fish and Wildlife Service, used Landsat Thematic Mapper images to develop the land cover dataset. The images reflect 1994 conditions. About two-thirds of the study area is classified as agricultural lands (Table 6). Urban land is approximately 4% of the watershed. Exhibits 5 and 6 provide more details on land use/land cover.

Table 6

LAND USE IN THE PIGEON CREEK WATERSHED
(Source: Indiana GAP Project, 1998)

Land Use	Area (ac)	Percentage
Other Non-vegetated	8,920	4%
Urban High Density	3,512	1%
Urban Low Density	7,335	3%
Agriculture Row Crop	113,055	48%
Agriculture Pasture/Grassland	46,728	20%
Shrubland	0	0%
Woodland	2,315	1%
Forest Deciduous	32,106	14%
Forest Evergreen	1,354	0.6%
Forest Mixed	2,339	1%
Wetland Forest	11,149	5%
Wetland Woodland	88	0.04%
Wetland Shrubland	1,243	0.5%
Wetland Herbaceous	920	0.4%
Wetland Sparsely Vegetated	816	0.3%
Water	3,347	1%
Total	235,226	100%

Corn, soybeans, wheat, and hay are the most common crops grown within the study area. Tillage systems in use on farms in the study area are discussed in Chapter 4. According to the Agricultural Census for Indiana, Gibson County had 579 farms totaling 232,839 acres in 1997. Warrick County had 356 farms totaling 98,549 acres, and Vanderburgh County has 271 farms totaling 72,112 acres. Crop and livestock statistics for the study area counties are given in Table 7. There are inconsistencies between statistics in Table 7 and Tables 3 through 6 that we attribute to likely differences between cropped farm land and non-cropped farm lands.

Table 7

CROP AND LIVESTOCK STATISTICS FOR WARRICK, GIBSON AND VANDERBURGH COUNTIES
(Source: Indiana Agriculture Statistical Service)

	Warrick	Gibson	Vanderburgh
Corn Planted (acres)	38,500	103,000	40,800
Soy Beans Planted (acres)	36,000	91,000	88,500
Winter Wheat Planted (acres)	7,500	33,200	n/a
Hay Harvested (acres)	5,800	5,300	1,500
Beef Cattle (inventory)	1,400	1,800	300
Dairy Cattle (inventory)	600	900	500

Note: All statistics based on 1999 data, except for the cattle numbers which are based on 2000 data.

2.2 WETLANDS

Prior to settlement by European immigrants, much of the study area was wetland. Today, there are very few wetlands. There are 14,216 wetland acres in the watershed or about 6%. Table 8 shows acreage of wetlands in each subwatershed of the study area. Forested wetland is the dominant wetland type remaining in the Pigeon Creek watershed.

Table 8

WETLANDS (acres) IN THE STUDY AREA
(Source: Indiana GAP Project)

	Subwatershed	Wetland Forest	Wetland Woodland	Wetland Shrubland	Wetland Herbaceous	Wetland Sparsely Vegetated	Water	Percent
1	Pigeon - Locust Creek Lower	253	11	26	29	61	50	7%
2	Locust Cr Headwater	62	18	15	0	4.2	86	2.8%
3	Pigeon - Kleymeyer Park	162	9.8	20.9	3.5	19	19	5.6%
4	Harper Ditch	454	0	0	14	17.6	73	8.5%
5	Pigeon - Crawford Brandeis	117	0	2.5	0	0	61	3.1%
6	Weinsheimer Ditch	104	0	0	39	10.3	24	2.0%
7	Pigeon - Barnes Ditch	1,586	3.3	140	139	83	452	18.2%
8	Blue Grass Cr – D Wagner	125	0	0	2.8	0	106	5.5%
9	Firlick Ditch	138	0	0	4.5	0	15	3.8%
10	Stubbs Fruedenberg Ditch	115	0	0	27	8.0	27	4.5%
11	Schlensker Ditch	89	0	0	0	11.6	23	2.7%
12	Little Pigeon Creek	265	7.5	26	15	0	108	3.8%
13	Unnamd Trib to Blue Grass Cr	87	0	0	19	15.7	94	4.1%
14	Blue Grass Cr Headwaters	166	0	8.0	7.3	7.4	34	3.6%
15	Clear Branch	2,527	18	404	113	171	474	25%
16	Squaw Creek	529	3.2	79	92	141	355	14%
17	Big Creek - Little Creek	461	0	53	100	48	615	12%
18	Big Creek Headwaters	792	4.7	84	121	101	439	13%
19	Big Creek - Wye	1,056	3.7	191	50	52	31	19%
20	Smith Fork Headwaters	194	0	0	22	44	125	2.6%
21	Smith Fork - Halfmoon Creek	1,001	0	168	73	17.8	72	12.5%
22	Snake Run	448	0	1.7	10	4.5	6.9	3.3%
23	Hurricane Ditch Creek	102	3.1	0	3.0	0	20	1.2%
24	West Fork Creek	67	5.7	5.5	3.5	0	30	0.6%
25	Clear Fork Ditch	169	0	15	21	0	4.9	1.8%
26	Sand Cr - Muddy Fork Ditch	80	0	3.7	10.0	0	1.4	0.8%
	TOTAL	11,149	88	1,243	920	816	3,347	7.5%

2.3 DEMOGRAPHICS AND DEVELOPMENT TRENDS

Evansville has developed into a center for manufacturing, warehousing, wholesaling and retailing, as well as insurance, finance and health services. The Evansville area is known for the production of appliances, nutritional products, pharmaceuticals, prepared foods, aluminum sheet and ingot processing, auto glass, coal and oil production, plastics including finished product, resins and pellets. The surrounding agricultural interests focus on production of corn, soybean and wheat.

The Evansville area has a diversified economy. Total non-agricultural wage and salaried employment in the Evansville area has risen from 125,200 in 1984 to 138,700 in 1990, an increase of 10.8 percent. Manufacturing employment over the past ten years has decreased, but employment in the service economy has increased, paralleling a national trend. Table 9 provides recent employment figures for non-agricultural sectors.

Table 9

NON-AGRICULTURAL EMPLOYMENT IN THE WATERSHED
(Source: Indiana Department of Employment and Training Services)

Total Non-Agricultural Wage & Salaried Employees	135,400
Total Manufacturing Employment	30,700
Nondurable Goods	15,500
Durable Goods	15,500
Total Non-Manufacturing Employment	104,700
Mining & Quarrying	2,100
Construction	7,300
Transportation, Communication & Utilities	7,000
Wholesale and Retail Trade	35,400
Finance, Insurance & Real Estate	5,300
Services	34,600
Government (including schools)	13,000

2.4 HISTORICAL WATER QUALITY

Historical water quality data for the study area were obtained from three sources: EWSU files, STORET, and IDEM. The US EPA water quality database STORET (STOrage and RETrieval) contains limited data for the study area, none more recent than March 1981. EWSU provided data for several sampling locations for the period November 1991 through March 1995. IDEM also provided data on several sampling locations, collected in 1999 and 2000. Exhibit 7 reprints all historical data available. Suitable long-term data for trend analysis are not available.

2.5 FISH

Fishes which historically were present in the watershed are listed in Table 10. Forty-three species were recorded by Gerking in his 1945 listing. All of the species listed are native to the watershed with the exception of the common carp. In their mid-1980s survey of the study area streams, Schultheis *et al.* (1987) found 39 species. The most abundant species in the drainage were creek chub, redfin shiner, blackstripe topminnow, silverjaw minnow, fathead minnow, bluntnose minnow, green sunfish and bluegill, respectively. Schultheis *et al.* stated that siltation appeared to be the most influential factor affecting fish populations and community structure of fishes in Pigeon Creek. They also found mosquitofish (*Gambusia affinis*) in Pigeon Creek, not recorded by Gerking. In their 1992 electrofishing survey of the lower portion of Pigeon Creek, the DNR found 21 species. Dominating their catch were the following fishes: gizzard shad, carp, white bass, longear sunfish, bluegill, and channel catfish.

A 1992 DNR electrofishing survey of the Uniontown Pool of the Ohio River did not include Pigeon Creek found 29 species in the Ohio River sections of Warrick and Vanderburgh Counties (Stefanavage 1994).

There is a fish consumption advisory for Vanderburgh County's portion of Pigeon Creek because of high concentrations of PCBs in fish tissue (ISDH *et al.* 2000). Channel catfish between 21 and 25 inches should be eaten no more than one meal every two months, and channel catfish larger than 25 inches should not be eaten at all. Largemouth bass larger than 13 inches and white crappie larger than 12 inches should not be eaten more than once each week.

Table 10

FISHES HISTORICALLY PRESENT IN THE PIGEON CREEK WATERSHED
(Source: Gerking 1945)

Scientific Name	Common Name
Lepisosteus osseus	Longnose gar
Alosa chrysochloris	Skipjack herring
Dorosoma cepedianum	Gizzard shad
Ictiobus bubalus	Smallmouth buffalo
Carpiodes cyprinus	Quillback
Erimyzon oblongus	Creek chubsucker
Minytrema melanops	Spotted sucker
Cyprinus carpio	Carp
Hybopsis storeriana	Silver chub
Hybopsis amblops	Bigeye chub
Notropis emiliae	Pugnose minnow
Notemigonus crysoleucas	Golden shiner
Notropis atherinoides	Emerald shiner
Notropis umbratilis	Redfin shiner
Luxilus cornutus	Common shiner
Notropis whipplei	Steelcolor shiner
Notropis volucellus	Mimic shiner
Phenacobius mirabilis	Suckermouth minnow
Hybognathus argyritis	Western silvery minnow
Pimephales promelas	Fathead minnow
Pimephales vigilax	Bullhead minnow
Pimephales notatus	Bluntnose minnow
Ictalurus punctatus	Channel catfish
Ictalurus melas	Black bullhead
Ictalurus nebulosus	Brown bullhead
Ictalurus natalis	Yellow bullhead
Pilodictis olivaris	Flathead catfish
Esox americanus	Pickerel
Fundulus notatus	Blackstripe topminnow
Fundulus notatus	Pirate perch

Table 10

FISHES HISTORICALLY PRESENT IN THE PIGEON CREEK WATERSHED
(Source: Gerking 1945)

Scientific Name	Common Name
Percina maculata	Blackside darter
Etheostoma nigrum	Johnny darter
Etheostoma chlorosomum	Bluntnose darter
Etheostoma flabellare	Fantail darter
Etheostoma gracile	Swamp darter
Micropterus punctatus	Spotted bass
Lepomis gulosus	Warmouth
Lepomis cyanellus	Green sunfish
Lepomis macrochirus	Bluegill
Lepomis megalotis	Longear sunfish
Pomoxis annularis	White crappie
Pomoxis nigromaculatus	Black crappie
Aplodinotus grunniens	Drum

2.6 THREATENED AND ENDANGERED SPECIES

The threatened and endangered species are protected under the Endangered Species Act (16 USC 1531 et seq.) of 1973. The goal of the act is to provide a means whereby the ecosystems upon which endangered and threatened species depend may be conserved and to restore all listed species to the point where their numbers make them viable self-sustaining members of their ecological communities.

We contacted the DNR Division of Nature Preserves with a request for information on the presence of threatened of endangered species and high quality natural communities within the study area. Table 11 lists the threatened and endangered species for the Pigeon Creek watershed by county. Exhibit 8 shows the general locations of the sightings.

Table 11

THREATENED AND ENDANGERED SPECIES IN THE STUDY AREA

Type	Species	Common Name	Fed Status	State Status	County
Amphibian	*Cryptobranchus alleganiensis alleganiensis*	hellbender	**	SE	V
Bird	*Botaurus lentiginosus*	American bittern	**	SE	W, G
Bird	*Ixobrychus exilis*	least bittern	**	SE	W, G
Bird	*Ardea herodias*	great blue heron	**	**	W
Bird	*Nyctanassa violacea*	yellow-crowned night-heron	**	SE	W
Bird	*Circus cyaneus*	northern harrier	**	SE	W
Bird	*Buteo lineatus*	red-shouldered hawk	**	SSC	W, G
Bird	*Rallus elegans*	king rail	**	SE	G
Bird	*Rallus limicola*	Virginia rail	**	SE	W
Bird	*Bartramia longicauda*	upland sandpiper	**	SE	V
Bird	*Tyto alba*	barn owl	**	SE	W, G
Bird	*Asio flammeus*	short-eared owl	**	SE	W
Bird	*Thryomanes bewickii*	Bewick's wren	**	SE	G
Bird	*Cistothorus platensis*	sedge wren	**	SE	G
Bird	*Lanius ludovicianus*	loggerhead shrike	**	SE	V
Bird	*Dendroica cerulea*	cerulean warbler	**	SSC	W
Bird	*Helmitheros vermivorus*	worm-eating warbler	**	SSC	W
Mammal	*Taxidea taxus*	American badger	**	SE	G
Reptile	*Nerodia erythrogaster neglecta*	copperbelly water snake	LTNL	SE	W, G
Crustacean	*Orconectes indianensis*	Indiana crayfish	**	SSC	V
Insect	*Nicrophorus americanus*	American burying beetle	LE	SX	V
Insect	*Catocala marmorata*	marbled underwing moth	**	**	V
Plant	*Perideridia americana*	Eastern eulophus	**	SE	W
Plant	*Krigia oppositifolia*	dwarf dandelion	**	ST	V, W
Plant	*Catalpa speciosa*	Northern catalpa	**	SR	W
Plant	*Phacelia ranunculacea*	blue scorpion-weed	**	SE	V
Plant	*Juglans cinerea*	butternut	**	WL	G
Plant	*Rhexia mariana var mariana*	Maryland meadow beauty	**	SE	V
Plant	*Bacopa rotundifolia*	roundleaf water-hyssop	**	SE	W
Plant	*Vitis palmata*	catbird grape	**	SR	V
Plant	*Carex socialis*	social sedge	**	SR	W,V
Plant	*Nothoscordum bivalve*	crow-poison	**	SR	W
Plant	*Isoetes melanopoda*	blackfoot quillwort	**	SE	V

Notes: SSC=State Special Concern, ST=State Threatened, SE=State Endangered, SR= State Rare, WL= Watch Listed, LE=Federal Endangered, LTNL=Federal Threatened
Counties: V=Vanderburgh, W=Warrick, G=Gibson

The Division of Nature Preserves also provided data on natural areas and communities in the watershed. These are listed below and also shown on Exhibit 5. These data do not include the recently opened 2,500-acre Blue Grass Fish and Wildlife Area near Elberfeld.

Table 12

NATURAL AREAS AND COMMUNITIES IN THE STUDY AREA
(Source: DNR Division of Nature Preserves)

Community	Counties
Wet-Mesic Floodplain Forest	V, G
Dry-Mesic Upland Forest	W, G
Dry Upland Forest	G
Mesic Upland Forest	V

Notes: V=Vanderburgh, W=Warrick, G=Gibson

3.0 WATERSHED BIOASSESSMENT

Water quality data was collected and bioassessments were performed in the Pigeon Creek watershed during August 1999 and May 2000. These sampling dates were selected to represent spring and summer seasons. Sampling and analytical methods are presented elsewhere (Harza 1999). Chemical, biological and habitat surveys were performed at 36 mainstem and tributary sampling stations (Exhibit 9). These samples were analyzed and used to characterize tributary subbasins (Exhibit 10).

3.1 CHEMICAL QUALITY

Water quality samples were collected in the study area at 36 sites. Samples were analyzed by Central States Analytical Labs, of Evansville, for conductivity, *E. coli*, total Kjeldahl nitrogen, nitrate+nitrite nitrogen, ammonia nitrogen, biochemical oxygen demand, pH, total phosphorus, and total dissolved solids. Laboratory reports are included in Appendix B. Field measurements were taken for water temperature, conductivity, pH, dissolved oxygen and flow. Samples were collected during the bioassessment surveys, which were performed during dry weather, or baseflow conditions. We also have collected wet weather samples from areas within the EWSU service area; these data are presented in Chapter 5.

Water samples were collected in polyethylene bottles pre-cleaned and supplied by the laboratory. Samples were collected prior to collecting biota or measuring flows. Following labeling, the bottles were placed on ice in a cooler, where they were kept until delivered to the laboratory later that day. Field water quality parameters were measured using a YSI model 6920 water quality data logger.

Water quality data collected as part of this study are included as Sheets 4 and 5 of Exhibit 7.

3.1.1 Temperature

Water temperature is important to organisms living in streams. Water temperature affects dissolved oxygen (DO) saturation limits, ammonia nitrogen ionization and toxicity, and habitat quality. There are no NPDES permitted thermal discharges in the watershed. Other sources include increased solar incidence due to removal of riparian vegetation, urban runoff, and treated wastewater discharges. Our grab sampling of temperature is primarily useful to estimate DO saturation and ammonia nitrogen ionization. Proper thermal studies of streams include diurnal monitoring to assess the daily maxima and minima, an indication of the degree to which solar incidence affects habitat quality.

3.1.2 Conductivity

Conductivity is the ability of water to carry an electric current and depends on the concentration of dissolved ions. It is an indirect measure of dissolved solids in the water. Typical dissolved solids include salts, organic materials, and nutrients. Sources of dissolved solids include weathering of soil and rocks, mined lands, oil brines and road salt.

Field measurements of conductivity were taken at each sampling point during the bioassessments of August 1999 and May 2000. While the highest measurement during the August field surveys was 3,800 µmhos/cm, very high conductivity of 6,309µmhos /cm was measured at PC15, downstream of Princeton and PC16, in the May survey. We do not know the source of the dissolved solids that caused that high measurement. It was not approached at the upstream (PC16) or downstream (PC14) sites.

3.1.3 Dissolved Oxygen

Dissolved oxygen (DO) is a measure of the amount of oxygen dissolved in the water column available to support aquatic life. DO levels near the saturation point indicate conditions favorable for a variety of life, while water with low DO is only able to support a few species. Many species suffer if DO levels fall below 3-4 mg/L. Streams absorb oxygen directly from the air and from aquatic plants undergoing photosynthesis. Supersaturated, DO concentrations (>100%) generally indicate nutrient enrichment, with photosynthesis causing the very high levels. Indiana's surface water quality standards dictate that DO levels shall average at least 5 mg/L per day and at no time should levels fall below 4 mg/L.

Field measurements of dissolved oxygen were taken at each sampling point during the bioassessments of August 1999 and May 2000. Several instances of both low dissolved oxygen and supersaturated dissolved oxygen were documented. Table 13 lists the measurements taken that were less than the four mg/L standard for dissolved oxygen, or, were greater than 125% supersaturated. Ten sites were below the standard during the August survey.

Table 13

SITES WITH DOCUMENTED DO SUPERSATURATION OR SITES NOT MEETING DO STANDARD

Condition	August 1999	May 2000
DO Saturation > 125%	HC1, WF1,WF2, SF1, SF2, PC14,	All sites excepts SD1 & PC14
DO < 4 mg/L	PC6, PC7, PC8, LC1, LC2, LP1, LP2, BC3, WD1, SD1	None

All but two monitoring sites were greater than 125% supersaturated with DO during the May survey. Oxygen supersaturation in low-gradient streams generally indicates nutrient enrichment in the waters. The high concentrations of DO are a result of photosynthesis from abundant attached filamentous or pelagic algae.

3.1.4 pH

Water's hydrogen ion concentration is expressed as pH. Measurements below neutral, pH 7.0, indicate higher hydrogen ion concentrations and that the water is acidic. Conversely, pH values above 7.0 show that the water is basic. Many aquatic organisms are sensitive to fluctuations in pH, and their reproduction processes are impeded under very acidic or very basic conditions in the water. Indiana's surface water standard dictate that pH should be in the range of 6–9, and variations exceeding 9 will be permitted if associated with photosynthetic activity.

All sites were slightly basic. During the August survey, pH ranged between 7.6 and 9.4. Two sites exceeded the pH 9 standard: WF2 (downstream of Fort Branch) and BC2 (Bluegrass Creek). During the May survey, pH ranged between 7.4 and 8.6.

3.1.5 Coliform Bacteria

Escherichia coli is the most widely known member of the coliform group of bacteria*. E. coli* is abundant in fecal matter and is often used as an indicator of sanitary discharges and pathogenic organisms. *E. coli* is estimated colony forming units (cfu) per 100ml of sample. Indiana's standard for recreational waters state "E. coli bacteria, using membrane filter (MF) count, shall not exceed one hundred twenty-five (125) colony forming units per one hundred (100) milliliters as a geometric mean based on not less than five (5) samples equally spaced over a thirty (30) day period nor exceed two hundred thirty-five (235) colony forming units per one hundred (100) milliliters in any one (1) sample in a thirty (30) day period" (IAC 327 2-1-6).

Samples were collected for measurement of *Escherichia coli* at each site during the bioassessments of August 1999 and May 2000, as well as during CSO and wet weather sampling. The results of the latter are presented in the Stream Reach Characterization and Evaluation (Chapter 5). Results from the August *E. coli* survey range from zero to 24,000 colony-forming units per 100 mL. Seventeen out of 36 sites were found to be in excess of the 125/100 mL water quality standard (Table 14) and an equal number, albeit at some different sites, exceeded the standard during the May survey. Nine sites exceeded the standard during both surveys: two locations on Pigeon Creek (PC6 and PC9), both sites on Locust Creek, both sites on Little Pigeon Creek, Weinsheimer Ditch, and all sites on West Fork Pigeon Creek (WF1, WF2, WF3) (Exhibit 11).

Table 14

SITES DOCUMENTED DURING DRY WEATHER TO EXCEED THE *E. COLI* STANDARD

August 1999	May 2000
PC6, PC7, PC8, PC9, PC 11, PC12, PC13, LC1, LC2, LP1, LP2, BC1, BC2, WD1, WF1, WF2, WF3	PC5, PC6, PC9, PC14, PC16, LC1, LC2, LP1, LP2, BC3, WD1, SD1, UN1, WF1, WF2, WF3, HC1

In their 305(b) assessment process, IDEM does not use the water quality standard to determine recreational use support of streams. IDEM considers streams with no more than one grab sample slightly exceeding 235 colonies/100mL and the geometric mean not exceeded to support recreational use. In the August survey, 13 sites exceeded 235/100mL. During the May survey, 12 sites exceeded 235/100mL.

3.1.6 Nitrogen

Nitrogen is also an essential nutrient in plant and animal growth, however in high concentrations it can inhibit such development. Natural waters contain nitrogen in the form of organic (or biomass) nitrogen, or in inorganic forms such as nitrate (NO_3), or nitrite (NO_2). In aerobic waters nitrate is usually the predominant form. Nitrogen can enter the stream through stormwater runoff from lands applied with organic or inorganic fertilizers. In this study, nitrate nitrogen, ammonia nitrogen and Kjeldahl nitrogen were all measured. Kjeldahl nitrogen is a measure of organic plus ammonia nitrogen.

The surface water quality standard set by the State for nitrite and nitrate is a maximum of 10 mg/L. This is based upon human health criteria and has no wildlife basis. Nitrate values for the August survey ranged from less than the detection limit of 0.05 mg/L as N at several sites, to a high of 6.7 mg/L at WF2 downstream of the Fort Branch wastewater treatment plant (WWTP) effluent on the West Fork Pigeon Creek. We also measured high nitrate at SD1, Stollberg Ditch at SR 62, of 5.4 mg/L as N.

Nitrate values for the May 2000 survey ranged from less than the detection limit of 0.05 mg/L as N at several sites, to a highs of 9.3 mg N/L at WF3, 8.9 at WF2 and 8.0 at WF1, all on West Fork Pigeon Creek. WF3 is upstream of all NPDES discharges and high nitrate levels there reflect agricultural nonpoint sources. We also measured high nitrate at SD1, Stollberg Ditch, of 5.7 mg N/L, and at Hurricane Creek, HC1, of 4.9 mg N/L; both SD1 and HC1 are downstream of WWTP discharges.

The surface water quality standard set by the State for ammonia nitrogen is pH and temperature dependent. Ammonia nitrogen values for the August survey ranged from less than 0.03 mg/L at PC3 (Pigeon Creek upstream of First Avenue), to a high of 2.88 mg/L at PC6, at US 41. Ammonia nitrogen values for the May survey ranged from 0.11 mg/L at PC6, to a high of 6.5 mg/L at PC9 (Stevenson Station Road). This high value at PC9 is suspect, as total Kjeldahl nitrogen (TKN) at PC9 during the May survey was 1.5 mg/L. As ammonia is operationally defined to be less than TKN, we attribute this value to laboratory error.

There is no state water quality standard for TKN. TKN values for the August 1999 survey ranged from less than the detection limit of 1.0 mg/L at several sites to 4.6 in Stollberg Ditch. TKN values for the May 2000 survey ranged from less than the detection limit of 1.0 mg/L at several sites to 10.0 in Stollberg Ditch. Other high TKN values found during May were at UN1, an unnamed tributary near Chandler, of 8.4 mg/L, and PC4, at Heidelbach Avenue of 5.0 mg/L.

3.1.7 Phosphorus

Phosphorus is also an essential nutrient for plant and animal growth. Excessive concentrations of phosphorus in the water column can lead to eutrophication of the stream. Only total phosphorus was analyzed in this study. Total phosphorus is commonly used as a measure of trophic status and includes particulate and dissolved phosphorus. Sources of phosphorus entering the stream include WWTP effluents, CSO discharges, yard wastes, animal wastes, and land-applied fertilizer. Phosphorus particles become bound to the soil, and surface runoff carries eroded soil particles to the stream. Phosphorus is an essential nutrient for plants and animals, but overenrichment causes excess plant growth and imbalances stream communities. The State of Indiana has no phosphorus water quality standard for use as a benchmark for comparison. The Illinois EPA's guideline is to classify a stream's aquatic life use support (ALUS) designation as impaired if total phosphorus exceeds 0.66 mg/L (IEPA 2000). Using this guideline as a reference, total phosphorus in many subwatersheds is quite high.

The range of total phosphorus in the August survey was from 0.02 mg/L at BG2 (Bluegrass Creek) to 7.2 mg/L at HC1, Hurricane Creek. The range of total phosphorus in the May survey was from 0.05 mg/L to 2.5 in Hurricane Creek and 2.4 in Stollberg Ditch (SD1). HC1 and SD1 are both downstream of WWTP discharges. Exhibit 12 shows the mean total phosphorus levels at each sampling location.

3.1.8 Suspended Solids

Particles suspended in the stream water column are referred to as suspended solids, and are operationally defined as being larger than 0.45 μm. Suspended solids enter a stream during wet weather runoff events, as a result of soil erosion or urban impervious surfaces wash-off. Suspended solids may also result from scour of the stream bank or bed during high flow events. Wastewater effluents and CSOs are additional sources. When flows diminish, suspended solids will tend to settle out, and can greatly degrade aquatic habitat. Both the quality and quantity of solids settling in streams affects fish and benthic fauna. Indiana has no water quality standard for suspended solids. For reference, the Illinois EPA considers streams having a TSS exceeding 116 mg/L more than once in three years to be impaired for ALUS.

The range of suspended solids in the August survey was from 2 mg/L at Smith Fork to 140 at LC2, in Locust Creek. The range of suspended solids in the May survey was from

from 3 mg/L at Smith Fork to 250 in Weinsheimer Ditch. Exhibit 13 shows the mean suspended solids levels at each sampling location.

3.1.9 Biochemical Oxygen Demand

Biochemical oxygen demand (BOD) is a laboratory measure of oxygen that is consumed as organic material by decays in the water. In this study, the laboratory measured BOD exerted over a five-day period at 23°C. Most measurements were less than the detection limit. The highest BOD measured during the August survey was 7.1 mg/L at Stollberg Ditch. The highest BOD measured during the May survey was 11 mg/L, also at the Stollberg Ditch.

3.2 PHYSICAL HABITAT

3.2.1 Discharge Measurements

At the time of the bioasessment survey, we measured several physical habitat parameters, including discharge. Flow measurements were taken using a Marsh McBirney model 201 portable flow meter. Results from stream flow measurements made immediately following sample collection are tabulated below. Discharge was not measurable in all locations as the site may not have been wadable (too deep or too precarious) or there may not have been enough flow to measure.

Table 15

DISCHARGE MEASUREMENTS

Site	Waterbody	Date	Discharge (cfs)	Date	Discharge (cfs)
PC1	Pigeon Creek	08/06/1999		5/12/00	
PC2	Pigeon Creek	08/07/1999		5/12/00	
PC3	Pigeon Creek	08/07/1999	7.9	5/08/00	
PC4	Pigeon Creek	08/07/1999	10.4	5/14/00	137
PC5	Pigeon Creek	08/07/1999	12	5/12/00	48
PC6	Pigeon Creek	08/09/1999		5/14/00	
PC7	Pigeon Creek	08/09/1999		5/12/00	
PC8	Pigeon Creek	08/09/1999		5/03/00	
PC9	Pigeon Creek	08/10/1999		5/10/00	
PC11	Pigeon Creek	08/11/1999	11.2	5/10/00	71
PC12	Pigeon Creek	08/12/1999	5.2	5/10/00	56
PC13	Pigeon Creek	08/13/1999	4.6	5/08/00	31
PC14	Pigeon Creek	08/15/1999	2.2	5/02/00	4.6
PC15	Pigeon Creek	08/05/1999	2.1	5/02/00	3.9
PC16	Pigeon Creek	08/05/1999	0.1	5/08/00	0.3
LC1	Locust Creek	08/08/1999	2.2	5/06/00	1.9
LC2	Locust Creek	08/10/1999		5/06/00	0.5
LP1	Little Pigeon Creek	08/08/1999	4.0	5/06/00	
LP2	Little Pigeon Creek	08/08/1999		5/06/00	1.0
BC1	Bluegrass Creek	08/09/1999	1.2	5/03/00	4.1
BC2	Bluegrass Creek	08/10/1999	1.2	5/03/00	2.6
BC3	Bluegrass Creek	08/11/1999		5/04/00	3.2
WD1	Weinsheimer Ditch	08/12/1999		5/04/00	9.7
SD1	Stollberg Ditch	08/13/1999	0.8	5/04/00	2.3
UN1	Unnamed Tributary	08/12/1999		5/04/00	1.0
SC1	Squaw Creek	08/11/1999	2.0	5/10/00	4.8
BG1	Big Creek	08/14/1999	0.7	5/07/00	12.8
BG2	Big Creek	08/13/1999		5/07/00	11.8
SF1	Smith Fork	08/14/1999	0.4	5/09/00	5.3
SF2	Smith Fork	08/14/1999	0.5	5/07/00	5.6
SF3	Smith Fork	08/14/1999	0.6	5/07/00	5.6
WF1	West Fork	08/15/1999	1.1	5/05/00	9.3
WF2	West Fork	08/15/1999	1.4	5/05/00	6.4
WF3	West Fork	08/15/1999	0.7	5/05/00	2.7
HC1	Hurricane Creek	08/15/1999	0.2	5/05/00	1.4
SA1	Sand Creek	08/06/1999		5/02/00	0.7

3.2.2 Qualitative Habitat Evaluation Index

Physical habitat was evaluated utilizing the Ohio EPA's Qualitative Habitat Evaluation Index (OEPA 1989). A 300-foot section of each of the 36 sites was inspected by a two-person field team. During the Qualitative Habitat Evaluation Index (QHEI) evaluation, scores are recorded on the data sheets for seven physical habitat metrics and the results are summed. These qualitative parameters include: substrate, instream cover, channel morphology, riparian zone and bank erosion, pool and glide quality, riffle and run quality, and gradient.

QHEI reflects the quality of stream physical habitat. In this procedure, the highest scores are assigned to the habitat parameters that have been shown to be correlated with streams having high biological diversity and integrity. Progressively lower scores are assigned to less desirable habitat features.

Tables 16 and 17, and Exhibits 14 and 15 show the QHEI results. Appendix C contains the QHEI field data sheets. Photographs taken during the field investigation are contained in Appendix C. IDEM considers streams to be fully supportive of aquatic life if the QHEI is equal to or exceeds 64. Streams with QHEI scores between 64 and 51 are considered by IDEM to be partially supportive and stream with QHEI scores less than 51 are not considered to be supportive of aquatic life (IDEM 2000). While scores changed slightly upon resurvey, none of the sites meet the IDEM's QHEI score to be considered fully supportive of aquatic life.

Agricultural land uses without conservation buffers along stream corridors have higher rates of sedimentation that other land uses. Urban land also can provide a source of sediment to streams from construction sites, unvegetated land, and accumulation of particles on streets and other hardened surfaces. These particles are transported by overland flow to streams where they are carried by the flow until they settle, and are deposited on the substrate. The adverse effects of sedimentation include burial of aquatic vegetation, macroinvertebrates and substrate interstitial spaces. In the QHEI, there are two means of scoring substrate quality. One involves the amount of silt cover on the substrate. The second is the degree of substrate embeddness caused by the deposition of silt particles on rocks and leaves on the substrate. The basis of the QHEI scoring of substrate quality is given in Tables 18 and 19. Again, higher values are indicative of increase in habitat quality.

Table 16

QUALITATIVE HABITAT EVALUATION INDEX FROM AUGUST 1999

Site	Water body	Substrate	Cover	Channel	Riparian	Pool	Riffle	Gradient	QHEI
PC1	Pigeon Creek	8	11	10	6	8	0	4	47
PC2	Pigeon Creek	11	12	7	4	8	0	2	44
PC3	Pigeon Creek	8	10	11	5	7	4	4	49
PC4	Pigeon Creek	17	6	10	7	5	2	4	51
PC5	Pigeon Creek	16	11	10	6	5	3	2	53
PC6	Pigeon Creek	7	8	11	6	8	0	2	42
PC7	Pigeon Creek	4	8	10	10	8	0	2	42
PC8	Pigeon Creek	6	8	10	7	8	0	4	43
PC9	Pigeon Creek	4	8	10	12	8	0	2	44
PC11	Pigeon Creek	14	6	10	10	7	2	4	53
PC12	Pigeon Creek	11	8	8	12	6	6	4	55
PC13	Pigeon Creek	14	9	7	12	6	2	2	52
PC14	Pigeon Creek	13	8	6	6	5	2	2	42
PC15	Pigeon Creek	15	9	7	6	4	3	4	48
PC16	Pigeon Creek	14	7	8	6	4	0	4	43
LC1	Locust Creek	12	11	11	6	9	2	2	53
LC2	Locust Creek	12	9	11	6	7	0	4	49
LP1	Little Pigeon Creek	5	8	8	10	9	3	4	47
LP2	Little Pigeon Creek	9	9	10	12	4	0	2	46
BC1	Bluegrass Creek	9	8	11	12	6	0	4	50
BC2	Bluegrass Creek	7	9	11	6	6	0	2	41
BC3	Bluegrass Creek	13	9	10	6	5	1	4	48
WD1	Weinsheimer Ditch	1	5	9	12	2	0	2	31
SD1	Stollberg Ditch	12	6	10	12	0	1	4	45
UN1	Unnamed Tributary	8	2	10	9	1	0	2	32
SC1	Squaw Creek	15	10	10	12	6	0	4	57
BG1	Big Creek	12	8	8	6	5	2	4	45
BG2	Big Creek	13	14	13	6	6	0	4	56
SF1	Smith Fork	11	7	8	12	5	1	4	48
SF2	Smith Fork	11	10	10	6	7	1	4	49
SF3	Smith Fork	12	13	11	10	9	2	4	61
WF1	West Fork	14	9	4	6	4	2	2	41
WF2	West Fork	12	9	7	6	6	4	2	46
WF3	West Fork	11	8	4	4	7	2	4	40
HC1	Hurricane Creek	14	5	8	6	5	2	4	44
SA1	Sand Creek	12	9	6	6	2	0	2	37

Table 17

QUALITATIVE HABITAT EVALUATION INDEX FROM MAY 2000

Site	Water body	Substrate	Cover	Channel	Riparian	Pool	Riffle	Gradient	QHEI
PC1	Pigeon Creek	7	8	7	5	8	4	4	43
PC2	Pigeon Creek	6	8	8	4	8	4	2	40
PC3	Pigeon Creek	3	7	8	5	8	5	4	40
PC4	Pigeon Creek	12	13	7	7	6	7	4	56
PC5	Pigeon Creek	11	9	7	12	6	3	2	50
PC6	Pigeon Creek	5	8	7	4	8	4	2	38
PC7	Pigeon Creek	5	8	7	10	8	4	2	44
PC8	Pigeon Creek	4	13	9	7	9	0	4	46
PC9	Pigeon Creek	2	6	7	12	8	4	2	41
PC11	Pigeon Creek	9	13	7	12	8	4	4	57
PC12	Pigeon Creek	12	8	7	12	8	5	4	56
PC13	Pigeon Creek	9	7	10	14	9	1	2	52
PC14	Pigeon Creek	13	8	7	6	5	2	2	43
PC15	Pigeon Creek	13	6	7	6	4	2	4	42
PC16	Pigeon Creek	14	8	10	9	6	5	4	56
LC1	Locust Creek	9	8	8	12	8	0	2	47
LC2	Locust Creek	14	13	10	6	4	2	4	53
LP1	Little Pigeon Creek	2	8	8	12	8	1	4	43
LP2	Little Pigeon Creek	11	9	8	12	5	2	2	49
BC1	Bluegrass Creek	9	5	7	12	4	0	4	41
BC2	Bluegrass Creek	7	6	7	6	3	0	2	31
BC3	Bluegrass Creek	10	6	8	6	4	0	4	38
WD1	Weinsheimer Ditch	2	6	7	11	8	2	2	38
SD1	Stollberg Ditch	5	6	7	12	5	0	4	39
UN1	Unnamed Tributary	2	6	7	9	3	1	2	30
SC1	Squaw Creek	14	9	8	12	8	5	4	60
BG1	Big Creek	12	12	8	5	7	4	4	52
BG2	Big Creek	12	9	11	12	8	4	4	60
SF1	Smith Fork	12	7	7	12	5	2	4	49
SF2	Smith Fork	11	8	9	6	4	2	4	44
SF3	Smith Fork	12	8	10	9	4	2	4	49
WF1	West Fork	10	8	7	6	4	1	2	38
WF2	West Fork	10	7	7	5	6	2	2	39
WF3	West Fork	11	8	9	4	6	1	4	43
HC1	Hurricane Creek	11	8	7	6	4	0	4	40
SA1	Sand Creek	11	9	7	6	5	1	2	41

Table 18

SUBSTRATE QUALITY SCORING FROM AUGUST 1999

Site	Water body	Silt Cover (points)	Extent of Embeddness (points)
PC1	Pigeon Creek	Heavy (-2)	Moderate (-1)
PC2	Pigeon Creek	Moderate (-1)	Moderate (-1)
PC3	Pigeon Creek	Moderate (-1)	Moderate (-1)
PC4	Pigeon Creek	Normal (0)	Moderate (-1)
PC5	Pigeon Creek	Moderate (-1)	Moderate (-1)
PC6	Pigeon Creek	Heavy (-2)	Extensive (-2)
PC7	Pigeon Creek	Heavy (-2)	Extensive (-2)
PC8	Pigeon Creek	Moderate (-1)	Moderate (-1)
PC9	Pigeon Creek	Heavy (-2)	Moderate (-1)
PC11	Pigeon Creek	Normal (0)	Low (0)
PC12	Pigeon Creek	Moderate (-1)	Moderate (-1)
PC13	Pigeon Creek	Normal (0)	Low (0)
PC14	Pigeon Creek	Moderate (-1)	Low (0)
PC15	Pigeon Creek	Normal (0)	None (+1)
PC16	Pigeon Creek	Moderate (-1)	Moderate (-1)
LC1	Locust Creek	Moderate (-1)	Moderate (-1)
LC2	Locust Creek	Moderate (-1)	Moderate (-1)
LP1	Little Pigeon Creek	Moderate (-1)	Moderate (-1)
LP2	Little Pigeon Creek	Moderate (-1)	Moderate (-1)
BC1	Bluegrass Creek	Moderate (-1)	Moderate (-1)
BC2	Bluegrass Creek	Heavy (-2)	Moderate (-1)
BC3	Bluegrass Creek	Normal (0)	Low (0)
WD1	Weinsheimer Ditch	Moderate (-1)	Moderate (-1)
SD1	Stollberg Ditch	Moderate (-1)	Moderate (-1)
UN1	Unnamed Tributary	Moderate (-1)	Moderate (-1)
SC1	Squaw Creek	Moderate (-1)	Low (0)
BG1	Big Creek	Normal (0)	Low (0)
BG2	Big Creek	Normal (0)	Low (0)
SF1	Smith Fork	Moderate (-1)	Low (0)
SF2	Smith Fork	Moderate (-1)	Low (0)
SF3	Smith Fork	Normal (0)	Low (0)
WF1	West Fork	Normal (0)	Low (0)
WF2	West Fork	Normal (0)	Low (0)
WF3	West Fork	Moderate (-1)	Low (0)
HC1	Hurricane Creek	Normal (0)	Low (0)
SA1	Sand Creek	Moderate (-1)	Moderate (-1)

Table 19

SUBSTRATE QUALITY SCORING FROM MAY 2000

Site	Water body	Silt Cover (points)	Extent of Embeddness (points)
PC1	Pigeon Creek	Moderate (-1)	Moderate (-1)
PC2	Pigeon Creek	Normal (0)	Moderate (-1)
PC3	Pigeon Creek	Heavy (-2)	Extensive (-2)
PC4	Pigeon Creek	Heavy (-2)	Extensive (-2)
PC5	Pigeon Creek	Normal (0)	Moderate (-1)
PC6	Pigeon Creek	Moderate (-1)	Moderate (-1)
PC7	Pigeon Creek	Moderate (-1)	Moderate (-1)
PC8	Pigeon Creek	Heavy (-2)	Extensive (-2)
PC9	Pigeon Creek	Heavy (-2)	Moderate (-1)
PC11	Pigeon Creek	Moderate (-1)	Moderate (-1)
PC12	Pigeon Creek	Normal (0)	Low (0)
PC13	Pigeon Creek	Moderate (-1)	Moderate (-1)
PC14	Pigeon Creek	Normal (0)	Low (0)
PC15	Pigeon Creek	Normal (0)	Low (0)
PC16	Pigeon Creek	Normal (0)	Low (0)
LC1	Locust Creek	Moderate (-1)	Extensive (-2)
LC2	Locust Creek	Normal (0)	Low (0)
LP1	Little Pigeon Creek	Moderate (-1)	Moderate (-1)
LP2	Little Pigeon Creek	Normal (0)	Low (0)
BC1	Bluegrass Creek	Moderate (-1)	Moderate (-1)
BC2	Bluegrass Creek	Heavy (-2)	Moderate (-1)
BC3	Bluegrass Creek	Heavy (-2)	Extensive (-2)
WD1	Weinsheimer Ditch	Heavy (-2)	Extensive (-2)
SD1	Stollberg Ditch	Heavy (-2)	Extensive (-2)
UN1	Unnamed Tributary	Heavy (-2)	Moderate (-1)
SC1	Squaw Creek	Normal (0)	Low (0)
BG1	Big Creek	Normal (0)	Low (0)
BG2	Big Creek	Normal (0)	Moderate (-1)
SF1	Smith Fork	Normal (0)	Low (0)
SF2	Smith Fork	Normal (0)	Low (0)
SF3	Smith Fork	Normal (0)	Low (0)
WF1	West Fork	Heavy (-2)	Extensive (-2)
WF2	West Fork	Moderate (-1)	Low (0)
WF3	West Fork	Moderate (-1)	Moderate (-1)
HC1	Hurricane Creek	Moderate (-1)	Moderate (-1)
SA1	Sand Creek	Moderate (-1)	Moderate (-1)

3.3 MACROINVERTEBRATE COMMUNITIES

The US EPA's Rapid Bioassessment Protocol II (RBP II) utilizes the systematic field collection and analysis of major benthic taxa. This protocol, long used for evaluation of point source discharges, is also appropriate for evaluating nonpoint source pollution and prioritizing sites for watershed management projects.

RBP II incorporates the concept of benthic analysis at the family taxonomic level. The technique utilizes field sorting and identification. The biological survey component of RBP II focuses on standardized sampling of benthic macroinvertebrates, supplemented by a cursory field observation of other aquatic biota such as periphyton, macrophytes, slimes and fish. The collection procedure provides representative samples of the macroinvertebrate fauna from riffle and run habitat types, and is supplemented with separate Course Particulate Organic Matter (CPOM) samples for the analysis of shredders and nonshredders. RBP II focuses on the riffle/run habitat because it is the most productive habitat available in stream systems and includes many pollution-sensitive taxa of the scraper and filtering collector functional feeding groups. This is why the technique, when properly implemented, can be a useful tool for evaluating pollution impacts and watershed management needs.

Our collections of macroinvertebrates included quantitative and qualitative sampling methods. Quantitative sampling included triplicate sampling with a Surber sampler in riffles and runs. Qualitative sampling included rock picking for clinging individuals and netting individuals swimming within the water column. CPOM was collected from available detritus, leaves and sticks and individuals were counted until at least 50 individuals were obtained to evaluate the ratio of shredders to the total number of individuals collected. All macroinvertebrates collected are listed on data sheets reprinted in Appendix C. Tables 20 and 21, and Exhibit 16, provide the macroinvertebrate survey results.

In the Pigeon Creek watershed, we sampled the benthos twice, in August 1999 and again in May 2000 at the same stations. Ideally we would have surveyed the watershed with each change of season, then select the appropriate sampling periods that accommodate seasonal variation. However, resident assemblages integrate stress effects over the course of the year, and their seasonal cycles of abundance and taxa composition are fairly predictable within the limits of interannual variability (Barbour *et al.* 1999). The composition of the benthos changes seasonally, as the source of energy and food changes. In the autumn, with the entry of leaves, or CPOM, to the stream, the feeding activities of a variety of macroinvertebrates collectively known as "shredders" may be very common.

These animals aid the breakdown of leaves and the production of fine particulate organic matter (FPOM). As the leaves breakdown and FPOM becomes increasing available, another feeding guild, the filterers, may be more common. In this way, the seasonality of trophic production in stream benthos tracks the entry of allochthanous organic matter.

Metrics used in the RBP indices evaluate aspects of elements and processes within the macroinvertebrate community. The indices do not incorporate metrics on individual condition, as is done with the fish-based Index of Biotic Integrity. The metrics in RBP II are taxa richness, Family Biotic Index, ratio of scrapers to filterers, ratio of EPT (Ephemeroptera, Plecoptera and Tricoptera) to Chironomidae, % contribution of dominant family, EPT index, ratio of shredders to nonshredders, and total individuals collected.

Taxa Richness is simply the total number of families present and represents biodiversity. Increasing diversity generally indicates with increasing health of the community and suggests that niche space, habitat, and food sources are adequate to support many species. This value generally increases with increasing water quality, habitat diversity and habitat suitability. During the August 1999 bioassessment, taxa richness varied from seven at PC4 (Pigeon Creek at Heidlebach Avenue) to 18 at two headwater sites (SF3 – Smith Fork, WF1 – West Fork). The average taxa richness during August 1999 was 13.2. During the May 2000 bioassessment, taxa richness varied from a low of five at SD1 (Stollberg Ditch) to 17 at PC8, Pigeon Creek at Hirsch Road. The average taxa richness during May 2000 was 13.2.

Modified Family Biotic Index (FBI) was developed to detect organic pollution and is based on the original species level index developed by Hilsenhoff in 1982. The modified FBI is a product of pollution tolerance values for family levels and the quantity of individuals within each family. Pollution tolerance values range from 0 to 10 for families and increase as water quality decreases. FBI during the August 1999 bioassessment ranged from 8.2 at BC2 (Bluegrass Creek) to 4.2 at PC4 (Pigeon Creek at Heidlebach Avenue). In fact, based solely on August FBI scores, lower Pigeon Creek would appear to have the highest water quality in the basin; FBI was 4.3 at PC5 (Stringtown Road) and 4.6 at PC 3 (First Avenue). Interestingly, these are within the CSO service area. The FBI at sites within the CSO service area averaged 5.62 in August. Basinwide, the average FBI in August was 6.0. FBI during the May 2000 bioassessment ranged from 7.9 at SC1 (Stollberg Ditch) to 5.3 at PC12 (Pigeon Creek east of Elberfield). The FBI at sites within the CSO service area averaged 6.43 in May. Basinwide, the FBI averaged 6.55 in May.

Feeding guilds of macroinvertebrates are enumerated in the RBP and used in two metrics. The ratio of the scrapers to filtering collectors reflects the riffle/run community food base. The relative abundance of scrapers and filtering collectors in the riffle/run habitat is indicative of periphyton community composition, availability of fine particulate organic material and the availability of attachment sites for filtering. Scrapers increase with an increase in diatom abundance and decrease in filamentous algae and aquatic mosses. Filamentous algae and aquatic mosses provide good attachment sites for filtering collectors and the organic enrichment often responsible for filamentous algae growth can also provide fine particulate organic material that is utilized by filtering collectors. Filtering collectors are also sensitive to toxicants bound to fine particles and should be the first group to decrease when exposed to steady sources of such bound toxicants. During the August 1999 bioassessment, the ratio of the scrapers to filterers ranged from lows of 0:77 at PC8 (Pigeon Creek at Hirsch Road) and 0:75 at PC8 (Pigeon Creek east of Elberfeld) to a high of 20:0 at SF2 (Smith Fork). During the May 2000 bioassessment, the ratio of the scrapers to filterers ranged from a low of 0:46 at PC12 (Pigeon Creek east of Elberfeld) to a high of 24:0 at LC2 (Locust Creek). Several sites in the CSO service area notably had high ratios for this metric: 9:0 at PC1, 22:0 at PC2 and 22:7 at PC3.

The ratio of EPT (Ephemeroptera-mayflies, Plecoptera-stoneflies and Trichoptera-caddisflies) to Chironomidae (midges) is an indicator of good biotic condition if the sensitive groups (EPT's) demonstrate a substantial representation. If the Chironomidae have a disproportionately large number of individuals in comparison to the sensitive groups then environmental stress is indicated. During the August 1999 bioassessment, the ratio of EPT to Chironomidae ranged from a low of 0:5 at UN1, the unnamed tributary, to a high of 20 at PC4 (Pigeon Creek at Heidelbach Avenue). During the May 2000 bioassessment, the ratio ranged from a low of 0:109 at SD1 (Stollberg Ditch) to a high of 2:1 at LP1 on Little Pigeon Creek.

Percent Contribution of Dominant Family uses the abundance of the numerically dominant taxon relative to the total number of organisms as an indication of community balance at the family level. Percent Contribution of Dominant Family during the August 1999 bioassessment ranged from a low of 0.16 at LC1 on Locust Creek to a high of 0.77 at SD1, Stollberg Ditch. Basinwide, this metric averaged 0.38 in August. Percent Contribution of Dominant Family during the May 2000 bioassessment ranged from a low of 0.18 at PC8, Pigeon Creek at Hirsch Road, to a high of 0.90, again at SD1, Stollberg Ditch. The average of all sites was 0.44 in May.

EPT Index value summarizes the taxa richness within the groups that are considered pollution sensitive and will generally increase with increasing water quality. This metric is the total number of distinct taxa within the groups Ephemeroptera, Plecoptera and Trichoptera. The EPT indices from the August 1999 bioassessment ranged from a low of 0 at UN1 (unnamed tributary) to a high of 6 at PC11, Pigeon Creek at Millersburg Bridge. The EPT index averaged 2.3 in August. In the May bioassessment, the EPT indices ranged from lows of 0 at ten sites (PC2, PC3, PC4, PC6 (all in the CSO service area), LC1, BC2, SD1, UN1, WF3, and HC1) to a high of 4, again at PC11. Basinwide, the EPT index averaged 1.2 in May.

The ratio of the shredder functional feeding group relative to the abundance of all other functional feeding groups also allows for the evaluation of potential impairment. Shredders are sensitive to riparian zone impacts and are particularly good indicators of toxic effects when the toxicants involved are readily adsorbed to the CPOM and either affect microbial communities colonizing the CPOM or the shredders directly (Plafkin, 1989). The ratio of shredders to nonshredders during the August 1999 bioassessment ranged from lows of 0:60 at twelve sites (PC4 and PC5 in the CSO service area, as well as PC12, PC13, BC1, BG2, SF1, SF2, WF1, WF2, WF3 and HC1) to a high of 0.50 at LC2 on Locust Creek. The ratio of shredders to nonshredders during the May 2000 bioassessment ranged from lows of 0:50 at five sites (PC2 and PC3 in the CSO service area, and PC9, PC12, and LC1) to a high of 0.74 at UN1, the unnamed tributary.

Table 20
MACROINVERTEBRATE MATRIX SCORES FROM AUGUST 1999

Site	Water	Taxa Richness	FBI	Scraper/ Filterer	EPT/ Chironomidae	% Contribution Dominant Family	EPT Index	Shredder/ Nonshredder	Total Number
PC1	Pigeon Creek	13	7.6	(12/0)	0.62	0.26	1	0.067	127
PC2	Pigeon Creek	14	6.3	(0/6)	0.070	0.27	1	0.033	105
PC3	Pigeon Creek	14	4.6	0.010	6.8	0.58	3	0.050	155
PC4	Pigeon Creek	7	4.2	(0/73)	20	0.61	2	(0/60)	119
PC5	Pigeon Creek	13	4.3	0.011	17	0.71	4	(0/60)	130
PC6	Pigeon Creek	16	6.7	5.5	0.25	0.22	2	0.20	141
PC7	Pigeon Creek	11	5.8	0.083	0.21	0.45	2	0.017	127
PC8	Pigeon Creek	12	4.9	(0/77)	3.0	0.50	2	0.067	155
PC9	Pigeon Creek	12	6.0	(0/1)	0.23	0.25	3	0.083	116
PC11	Pigeon Creek	11	4.8	0.13	6.1	0.48	6	0.033	129
PC12	Pigeon Creek	8	4.6	(0/75)	7.9	0.49	2	(0/60)	144
PC13	Pigeon Creek	13	5.3	0.058	2.4	0.35	3	(0/60)	123
PC14	Pigeon Creek	12	5.9	0.29	2.8	0.34	4	0.017	140
PC15	Pigeon Creek	15	5.2	0.016	13	0.37	3	0.033	118
PC16	Pigeon Creek	11	7.4	89	(3/0)	0.65	2	0.016	129
LC1	Locust Creek	12	6.0	0.41	1.1	0.16	1	0.033	115
LC2	Locust Creek	16	6.7	3.0	0.023	0.21	1	0.50	174
LP1	Little Pigeon Cr	13	5.9	0.15	1.6	0.45	3	0.050	145
LP2	Little Pigeon Cr	13	5.1	5.5	2.2	0.39	3	0.10	145
BC1	Bluegrass Creek	11	5.6	0.16	1.7	0.35	1	(0/60)	115
BC2	Bluegrass Creek	15	8.2	1.0	0.057	0.40	2	0.017	150
BC3	Bluegrass Creek	15	6.4	2.9	1.7	0.30	3	0.050	185
WD1	Weinsheimer D	12	6.0	2.0	3.4	0.30	2	0.033	147
SD1	Stollberg Ditch	9	7.7	2.0	0.040	0.77	1	0.017	121
UN1	Unnamed Trib	16	6.7	33	(0/5)	0.41	0	0.18	118
SC1	Squaw Creek	12	6.3	(0/61)	1.6	0.25	2	0.050	138
BG1	Big Creek	14	5.8	0.19	0.36	0.28	3	0.017	135
BG2	Big Creek	16	6.4	0.040	0.63	0.21	2	(0/60)	121
SF1	Smith Fork	17	5.6	0.44	1.5	0.19	2	(0/60)	131
SF2	Smith Fork	14	7.0	(20/0)	0.38	0.21	2	(0/60)	129
SF3	Smith Fork	18	5.4	0.11	2.4	0.31	5	0.33	130
WF1	West Fork	18	6.1	0.15	2.2	0.30	3	(0/60)	155
WF2	West Fork	14	5.4	0.11	0.94	0.38	2	(0/60)	128
WF3	West Fork	16	7.8	2.0	0.040	0.37	1	(0/60)	107
HC1	Hurricane Creek	12	6.7	17	0.11	0.28	2	(0/60)	122
SA1	Sand Creek	10	6.4	1.2	0.063	0.47	2	0.048	128

Table 21
MACROINVERTEBRATE MATRIX SCORES FROM MAY 2000

Site	Water	Taxa Richness	FBI	Scraper/ Filterer	EPT/ Chironomidae	% Contribution Dominant Family	EPT Index	Shredder/ Nonshredder	Total Number
PC1	Pigeon Creek	13	6.8	(9/0)	0.38	0.22	2	0.10	119
PC2	Pigeon Creek	8	6.4	(20/0)	(0/80)	0.67	0	(0/50)	104
PC3	Pigeon Creek	10	6.2	(22/0)	(0/57)	0.56	0	(0/50)	116
PC4	Pigeon Creek	9	6.3	(0/7)	(0/88)	0.68	0	0.16	127
PC5	Pigeon Creek	15	6.8	0.11	0.091	0.36	2	0.060	152
PC6	Pigeon Creek	10	6.1	2.0	(0/65)	0.51	0	0.020	123
PC7	Pigeon Creek	15	7.3	0.92	0.12	0.42	1	0.50	134
PC8	Pigeon Creek	17	6.6	1.9	0.44	0.18	2	0.091	112
PC9	Pigeon Creek	11	6.7	(1/0)	0.053	0.44	1	(0/50)	190
PC11	Pigeon Creek	14	6.0	0.10	0.11	0.73	4	0.020	145
PC12	Pigeon Creek	11	5.3	(0/46)	0.67	0.48	3	(0/50)	143
PC13	Pigeon Creek	14	7.3	(2/0)	1.4	0.27	1	0.040	134
PC14	Pigeon Creek	9	5.9	0.082	0.95	0.23	1	0.36	163
PC15	Pigeon Creek	14	7.2	0.074	0.020	0.28	1	0.27	152
PC16	Pigeon Creek	16	6.8	14	0.010	0.47	1	0.18	184
LC1	Locust Creek	6	6.1	(0/5)	(0/102)	0.84	0	(0/50)	114
LC2	Locust Creek	12	6.7	(24/0)	0.37	0.33	2	0.64	162
LP1	Little Pigeon Cr	9	5.9	(2/0)	2.0	0.32	1	0.10	117
LP2	Little Pigeon Cr	11	6.4	1.5	0.47	0.37	2	0.61	142
BC1	Bluegrass Creek	13	6.6	1.4	0.11	0.53	2	0.020	110
BC2	Bluegrass Creek	8	6.9	34	(0/68)	0.39	0	0.060	174
BC3	Bluegrass Creek	14	7.0	34	0.31	0.24	2	0.14	143
WD1	Weinsheimer D	16	6.6	9.0	0.077	0.38	1	0.020	101
SD1	Stollberg Ditch	5	7.9	(2/0)	(0/109)	0.90	0	0.020	117
UN1	Unnamed Trib	10	7.0	0.063	(0/14)	0.50	0	0.74	153
SC1	Squaw Creek	12	7.0	(0/1)	0.44	0.47	2	0.52	110
BG1	Big Creek	12	6.0	(0/16)	1.6	0.29	1	0.060	152
BG2	Big Creek	16	6.2	0.060	0.23	0.38	2	0.040	126
SF1	Smith Fork	15	6.0	0.025	1.4	0.31	3	0.57	134
SF2	Smith Fork	10	6.4	(0/37)	0.40	0.34	2	0.060	122
SF3	Smith Fork	9	7.5	(1/0)	0.83	0.46	1	0.31	138
WF1	West Fork	14	6.2	0.030	0.012	0.52	1	0.020	132
WF2	West Fork	14	6.5	0.86	0.038	0.38	1	0.020	130
WF3	West Fork	12	5.6	7.0	(0/55)	0.36	0	0.10	177
HC1	Hurricane Creek	10	7.2	(10/0)	(0/91)	0.70	0	0.02	129
SA1	Sand Creek	10	6.3	0.35	0.013	0.34	1	0.14	169

3.4 SUMMARY OF TRIBUTARY HEALTH

The 26 subwatersheds in the study area have been characterized using bioassessment data from 36 locations. Key indicators are judged to be fecal coliform bacteria, nutrient concentrations, suspended solids concentrations, substrate siltation scores and FBI, the Family Biotic Index. The FBI was selected as the key benthic indicator as it incorporates both diversity and pollution tolerance. Recall that higher FBI scores are an indicator of an aquatic system under stress.

Exhibits 17 and 18 includes the above mentioned key watershed health variables and our ranking of monitoring sites into four groups by quartile. To categorize sites accordingly, we assigned points to each, from zero to five, with zero being the most pristine site. The worst site(s) received five points.

While all subwatersheds are impaired for aquatic life support to some degree, among the more healthy subwatersheds are those included in the first quartile. These areas most warrant protection against degradation, and include principally Smith Fork (subwatersheds 20 and 21), West Fork Pigeon Creek (subwatershed 24) and Big Creek (subwatersheds 17, 18 and 19).

In Chapter 4, point and nonpoint sources of pollution are identified, and nonpoint sources are estimated. In Chapter 5, we present a statistical analysis of correlation between these biotic factors, and pollution loadings. Chapter 5 further ranks subwatersheds by their relative need for nonpoint source investments.

Table 22

RELATIVE TRIBUTARY BIOTIC INTEGRITY

Monitoring Site	Water Body	Points	Rank
	First Quartile		
SF3	Smith Fork	13	1
BG1	Big Creek	16	2
BG2	Big Creek	16	3
PC15	Pigeon Creek	18	4
SF1	Smith Fork	18	5
SF2	Smith Fork	18	6
PC14	Pigeon Creek	20	7

Table 22

RELATIVE TRIBUTARY BIOTIC INTEGRITY

Monitoring Site	Water Body	Points	Rank
SA1	Sand Creek	22	8
LP2	Little Pigeon Creek	23	9
	Second Quartile		
PC4	Pigeon Creek	24	10
PC5	Pigeon Creek	24	11
PC12	Pigeon Creek	24	12
SC1	Squaw Creek	24	13
WF1	West Fork	25	14
PC2	Pigeon Creek	26	15
PC11	Pigeon Creek	26	16
PC16	Pigeon Creek	27	17
LC1	Locust Creek	27	18
	Third Quartile		
WF2	West Fork	27	19
WF3	West Fork	27	20
PC13	Pigeon Creek	28	21
PC1	Pigeon Creek	29	22
PC3	Pigeon Creek	29	23
BC1	Bluegrass Creek	30	24
LP1	Little Pigeon Creek	31	25
LC2	Locust Creek	33	26
UN1	Unnamed Tributary	33	27
	Fourth Quartile		
HC1	Hurricane Creek	33	28
PC8	Pigeon Creek	35	29
BC3	Bluegrass Creek	35	30
WD1	Weinsheimer Ditch	35	31
PC7	Pigeon Creek	36	32
BC2	Bluegrass Creek	37	33
PC6	Pigeon Creek	39	34
PC9	Pigeon Creek	41	35
SD1	Stollberg Ditch	41	36

4.0 POLLUTION SOURCES

Both natural and human activities can modify the landscape and cause pollutants to enter waterways. Pollutant sources are divided into two broad categories: point sources and nonpoint sources. Point sources are traceable to a single point of discharge into the waterway and are usually regulated by state or federal permits (such as National Pollutant Discharge Elimination System (NPDES) Permits). Municipal treatment plants and industrial facilities are examples of point source discharges. Nonpoint source pollution comes from the watershed land surface, and can be difficult to trace to any one particular site. Typically, nonpoint source pollutants are transported to the waterbody via stormwater or snowmelt runoff. Sediments and nutrients are common pollutants that are washed from agricultural fields or construction sites during runoff events. In this chapter we summarize point and nonpoint pollution sources in the study area.

4.1 POINT SOURCES

Evansville is the largest community in the watershed, having a 1990 population of 126,272 person residing in 53,058 households. Other communities in the watershed include Chandler, Elberfeld, Fort Branch, Haubstedt, and portions of Owensville and Princeton. Many of these communities, as well as some industrial facilities, are permitted to discharge treated wastewater to directly to Pigeon Creek or its tributaries (Table 23, Exhibits 18 and 19). In this section we qualitatively evaluate the effects of these discharges on watershed health. Where possible, we relate NPDES compliance with our bioassessment data. The EWSU CSOs are addressed in detail in the following chapter.

Table 23

NPDES DISCHARGES TO PIGEON CREEK
(Source: USEPA Permit Compliance System)

FACILITY	RECEIVING WATER	HUC	NPDES
Indiana Hardwoods, Kimball Intern'l	Pigeon Cr via Strollberg D via D.	05140202030070	IN0058530
EWSU - Westside Plant	Ohio R (except certain CSOs)	05140202040	IN0032956
EWSU - Eastside Plant	Ohio R (except certain CSOs)	05140202040	IN0033073
Chandler Municipal WWTP	Pigeon Cr via Strollberg Ditch	05140202030070	IN0020435
Haubstadt Municipal WWTP	West Fork Pigeon Cr via Haubstadt (aka Hurricane) Ditch	05140202020030	IN0021482
Solar Sources Inc. - Pit 12	Smith Fork Cr Honey Cr Rough Cr.	05140202020060	IN0047970
Darmstadt Municipal WWTP	Pigeon Cr via Little Pigeon Creek	05140202040090	IN0052990
Lynnville Municipal WWTP	Pigeon via Big Cr via Mill Cr	05140202040010	IN0040282
Elberfeld Municipal WWTP	Pigeon Cr via Bluegrass Creek	05140202040020	IN0020788
Warrick Cnty Coal-Lynnville	Pigeon Cr via Big Cr via Plum B	05140202040010	IN0047287
Cargill Meat Products	West Fork Pigeon Creek via Toops Ditch	05140202020040	IN0001686
Fort Branch Municipal WWTP	West Fork Pigeon Creek	05140202020040	IN0022896
Mid-State Rubber Products	West Fork Pigeon Creek via storm sewer	05140202020040	IN0004880

4.1.1 Stollberg Ditch

Stollberg Ditch drains a portion of Hydrologic Unit Code (HUC) 05140202030070. We included this stream in our bioassessment. Stollberg Ditch was found it to contain some of the highest TSS, BOD, phosphorus, nitrate and ammonia nitrogen concentrations, and some of the lowest DO levels among sites we surveyed in the watershed. We also found low benthic diversity and an absence of sensitive macroinvertebrate taxa (mayflies, stonefiles, caddisflies). Stollberg Ditch is the receiving water for two NPDES discharges: Chandler Municipal Wastewater Treatment Plant (WWTP) and Indiana Hardwoods. Chandler WWTP was issued a new NPDES permit on June 18, 1999 to discharge 1.8 million gallons per day of treated sanitary wastewater into Stollberg Ditch. The facility is currently being upgraded to a major plant, with construction nearing completion. According to the new permit, effluent parameters to be limited and/or monitored include flow, carbonaceous BOD_5, total suspended solids, ammonia nitrogen, pH, dissolved oxygen, total residual chlorine and *E. coli.* The Chandler WWTP has a history of being overloaded, bypassing of sewage, and regular noncompliance reports (USEPA Permit Compliance System).

Indiana Hardwoods, of Kimball International, Inc. is a manufacturer of hardwood veneers and plywoods. Indiana Hardwoods also has a permit to discharge to Stollberg Ditch. Permit IN0058530 expires December 31, 2000. According to the Permit Compliance System, their wastewater is from the washing of logs in the yard. They are required to monitor pH, ammonia nitrogen, flow and carbonaceous BOD_5. The facility has an apparently good compliance record, with two reportable noncompliance events recorded between March 1996 and July 2000.

4.1.2 West Fork Pigeon Creek

Two municipal and one industrial point source discharges are permitted in this drainage. The Haubstadt Municipal WWTP discharges to Haubstadt Ditch, a tributary of Hurricane Ditch, HUC 05140202020030, which drains to the West Fork Pigeon Creek HUC 05140202020040. The Town of Haubstadt WWTP was issued a new NPDES Permit, No. IN0021482, in November 1999 to discharge 0.81 million gallons per day of treated sanitary wastewater into Haubstadt Ditch. HC1 was one of our bioassessment sites, downstream of the Haubstedt WWTP. We found high concentrations of nitrate, phosphorus and coliform bacteria. The RBP results included very low numbers of sensitive taxa at HC1, a lack of shredders and a dominance of filterers. The permit requires that certain effluent parameters be limited and/or monitored at the WWTP: flow, carbonaceous BOD, total suspended solids, ammonia nitrogen, pH, dissolved oxygen and total residual chlorine. In July 2000, the Town approved IDEM-mandated upgrades to the WWTP to reduce wet weather overflows and to improve effluent quality. IDEM required the upgrades due to the Haubstadt WWTP’s history of regular noncompliance reporting.

The Town of Fort Branch WWTP discharges to the West Fork Pigeon Creek (Permit No. IN0022896). This WWTP was issued a new permit on July 31, 1998 to discharge 0.655 million gallons per day of treated sanitary wastewater into the West Fork of Pigeon Creek. It is a minor municipal wastewater treatment facility, and is required to monitor and or limit the following effluent parameters: flow, carbonaceous BOD, total suspended solids, ammonia nitrogen, dissolved oxygen, total residual chlorine and pH. There are sanitary sewer overflows in this system during wet weather. Since the new permit was issued, the permittee has reported four noncompliance events. We also had bioassessment sites on the West Fork Pigeon Creek. We found supersaturation DO, high concentrations of coliform bacteria, and nitrate.

Cargill Processed Meat Products, of Fort Branch, was issued a new NPDES permit on May 14, 1999 (IN0001686). The permit allows the owner to discharge 0.272 million gallons per day of meat products processing wastewater into Toops Ditch, tributary to West Fork of Pigeon Creek. The permit requires the owner to limit or monitor the following effluent parameters: flow, BOD_5, total suspended solids, oil and grease, ammonia nitrogen, fecal coliform bacteria, total residual chlorine and pH. The facility is apparently well operated, without reports of noncompliance in the EPA's Permit Compliance System.

Mid-State Rubber Products, Inc. is in Princeton, IN. This industrial concern was issued a NPDES storm water permit on June 7, 1999 (IN0004880). The permittee manufactures molded, extruded, and lathe-cut mechanical rubber goods.

4.1.3 Big Creek

On April 27, 1998, NPDES Permit No. IN0040282 was renewed for the Town of Lynnville. The permit allows the WWTP to discharge 0.1 million gallons per day of treated sanitary wastewater into an unnamed tributary to Mill Creek, which discharges to Big Creek (HUC 05140202040010) in Warrick County. The facility is considered a minor municipal wastewater treatment plant. The permit requires the following effluent parameters to be limited and/or monitored: flow, carbonaceous BOD_5, total suspended solids, ammonia nitrogen, dissolved oxygen, pH and total residual chlorine. Review of the EPA's Permit Compliance System database indicates two noncompliance reports since the permit was renewed.

Warrick County Coal had an NPDES permit to discharge to Big Creek, Permit No. IN0047287. The Permit Compliance System no longer includes this permit, so it has likely been abandoned.

4.1.4 Bluegrass Creek

Bluegrass Creek is the receiving water for Elberfeld WWTP, located in HUC 05140202040020. The facility is permitted to discharge 0.3 millon gallons per day of treated municipal wastewater to Bluegrass Creek. The permit requires the following effluent parameters to be limited and/or monitored: flow, carbonaceous BOD_5, total suspended solids, ammonia nitrogen, dissolved oxygen, pH and total residual chlorine. While the facility has a poor compliance record, with numerous noncompliance reports in the EPA's Permit Compliance System database, the bioassessment sites on Bluegrass Creek did not indicate significant impairment. Elberfeld's WWTP is currently being upgraded.

4.1.5 Lower Pigeon Creek

While the EWSU wastewater treatment plants discharge to the Ohio River, the sewer system carries both stormwater and wastewater, and there are nine combined sewer outfalls that discharge to Pigeon Creek during wet weather. These discharges are permitted under NPDES Permits IN0032956 and IN0033073, which require the preparation of a Stream Reach Characterization Evaluation Report (Chapter 5) evaluating the impacts of these CSOs.

4.2 NONPOINT SOURCES

The nonpoint sources of pollution to Pigeon Creek are attributable to stormwater runoff from the surrounding watershed. Stormwater runoff can carry considerable sediment, nutrients, and other pollutants, depending on land use, slope, vegetative cover and other factors. The principal nonpoint sources in the study area watershed are agricultural cropland runoff and urban runoff. Minor sources include animal feeding operations and unvegetated mined land.

4.2.1 Cropland Management

Long term data on farm and cropland management are not available for this watershed. Recently, Purdue University has coordinated the collection of cropland management data statewide. For Pigeon Creek watershed, HUC 05140202, these data are available for the years 1997, 1998 and 2000 through the Transect database (Hess 2000). Transect is a computer program developed at Purdue University for Indiana's T-by-2000 soil conservation education program to summarize data collected from roadside surveys of agricultural land. These surveys are designed to collect information on agricultural practices, with a focus on tillage systems and crop residue management.

Tables 24 through 27 contain data extracted from Transect on a watershed basis. Watershed and subwatershed boundaries for these codes are shown in Exhibit 10. Cropland area in the watershed has been reasonably constant since 1997. HUC 05140202020, which is largely in Gibson County, has the most cropland in the study area, nearly two-thirds. Watershed wide, conservation tillage systems were used on 25% of cropland in 1997, 16% of cropland in 1998, and 33% of cropland in 2000. Data on the conservation tillage in the watersheds are insufficient to demonstrate trends. In the year 2000, HUC 05140202030, which is principally Warrick County, had a high of 51% of cropland in conservation tillage.

Table 24

CROPLAND ACREAGE AND TILLAGE SYSTEMS, 1997 – 2000
(Source: Transect Program, Hess 2000)

Year – 1997							
Watershed	**No-till**	**Ridge-till**	**Mulch-till**	**Reduced-till**	**Conventional**	**N/A**	**Total**
05140202 020	10,541	0	2,108	0	45,676	12,297	70,622
05140202 030	5,540	0	494	0	7,439	2,042	15,515
05140202 040	5,192	0	4,700	0	10,877	5,377	26,146
Total	21,272	0	7,302	0	63,991	19,717	112,283
Year – 1998							
Watershed	**No-till**	**Ridge-till**	**Mulch-till**	**Reduced-till**	**Conventional**	**N/A**	**Total**
05140202 020	4,927	0	704	0	52,088	13,726	71,445
05140202 030	4,095	0	261	0	9,155	2,700	16,211
05140202 040	3,857	0	4,004	0	12,194	5,677	25,732
Total	12,879	0	4,969	0	73,437	22,103	113,388
Year – 2000							
Watershed	**No-till**	**Ridge-till**	**Mulch-till**	**Reduced-till**	**Conventional**	**N/A**	**Total**
05140202 020	13,843	0	2,485	1,775	44,724	8,874	71,700
05140202 030	7,074	265	530	530	5,660	2,385	16,444
05140202 040	7,603	0	2,179	795	10,431	3,920	24,929
Total	28,521	265	5,194	3,100	60,814	15,179	113,073

Conservation tillage leaves significantly more plant residue on the land than conventional tillage. The residue protects soil from the energy of rainfall, which would otherwise dislodge soil particles and make them available for transport from the field to waterways. For this reason, soil conservation agencies have been encouraging conservation tillage for several years. Data from Pigeon Creek cropland reflects higher residue on fields that utilize no-till, ridge-till, mulch-till or reduced till systems (Table 25). In hydrologic unit 05140202020, which is largely Gibson County, 21% of the cropland has at least 30% residue cover on the soil surface. In HUC 05140202030, which is principally Warrick County, 46% of cropland has at least 30% residue cover. In HUC 05140202040, which is largely Vanderburgh County, 39% of cropland has at least 30% residue cover.

Table 25

RESIDUE COVER CLASSES FOR EACH TILLAGE SYSTEM (acres) in 2000
(Source: Transect Program, Hess 2000)

Watershed - 05140202 020					
Tillage System	**0-15%**	**16-30%**	**>30%**	**N/A**	**Total**
No-till	0	0	12,423	1,420	13,843
Ridge-till	0	0	0	0	0
Mulch-till	0	0	2,485	0	2,485
Reduced-till	0	1,775	0	0	1,775
Conventional	44,724	0	0	0	44,724
N/A	0	0	0	8,874	8,874
Total	44,724	1,775	14,908	10,294	71,700
Watershed - 05140202 030					
Tillage System	**0-15%**	**16-30%**	**>30%**	**N/A**	**Total**
No-till	0	0	7,074	0	7,074
Ridge-till	0	0	265	0	265
Mulch-till	0	265	265	0	530
Reduced-till	265	265	0	0	530
Conventional	5,660	0	0	0	5,660
N/A	265	0	0	2,120	2,385
Total	6,190	530	7,604	2,120	16,444
Watershed - 05140202 040					
Tillage System	**0-15%**	**16-30%**	**>30%**	**N/A**	**Total**
No-till	0	265	7,338	0	7,603
Ridge-till	0	0	0	0	0
Mulch-till	0	265	1,914	0	2,179
Reduced-till	0	530	265	0	795
Conventional	9,901	265	265	0	10,431
N/A	0	0	0	3,920	3,920
Total	9,901	1,325	9,782	3,920	24,929

In addition to the amount of crop residue remaining on the land following harvest, other factors affecting the rate soil erodes include growing season vegetative cover, slope, soil type, and rainfall variables. Information on vegetative cover on croplands in the study area is detailed in Table 26. Soybeans are the most common crop farmed using conservation tillage systems.

Table 26
CROP ACREAGE BY TILLAGE SYSTEM IN 2000
(Source: Transect Program, Hess 2000)

Watershed - 05140202 020						
Tillage System	**Corn**	**Soybeans**	**Small grains**	**Forage**	**Idle**	**Total**
No-till	5,679	6,744	1,420	0	0	13,843
Ridge-till	0	0	0	0	0	0
Mulch-till	1,420	1,065	0	0	0	2,485
Reduced-till	710	1,065	0	0	0	1,775
Conventional	38,689	6,034	0	0	0	44,724
N/A	0	0	8,874	0	0	8,874
Total	46,498	14,908	10,294	0	0	71,700
Watershed - 05140202 030						
Tillage System	**Corn**	**Soybeans**	**Small grains**	**Forage**	**Idle**	**Total**
No-till	3,800	3,275	0	0	0	7,074
Ridge-till	0	265	0	0	0	265
Mulch-till	265	265	0	0	0	530
Reduced-till	265	265	0	0	0	530
Conventional	4,070	1,590	0	0	0	5,660
N/A	0	0	1,590	530	265	2,385
Total	8,399	5,660	1,590	530	265	16,444
Watershed - 05140202 040						
Tillage System	**Corn**	**Soybeans**	**Small grains**	**Forage**	**Idle**	**Total**
No-till	4,185	3,418	0	0	0	7,603
Ridge-till	0	0	0	0	0	0
Mulch-till	589	1,590	0	0	0	2,179
Reduced-till	795	0	0	0	0	795
Conventional	6,246	4,185	0	0	0	10,431
N/A	0	0	2,152	914	854	3,920
Total	11,816	9,193	2,152	914	854	24,929

Land slopes planted to various crops are given in Table 27. Steeper slopes are much more prone to excessive erosion than shallower slopes.

Table 27

SLOPE OF LANDS (acres) PLANTED TO VARIOUS CROPS
(Source: Transect Program, Hess 2000)

Watershed – 05140202 020						
Present crop	**0-2%**	**3-4%**	**5-7%**	**8-10%**	**>10%**	**Total**
Corn	26,266	8,519	5,679	5,679	355	46,498
Soybeans	7,099	4,259	3,195	355	0	14,908
Small grains	3,904	3,904	1,420	1,065	0	10,294
Forage	0	0	0	0	0	0
Idle	0	0	0	0	0	0
Total	37,270	16,683	10,294	7,099	355	71,700
Watershed – 05140202 030						
Present crop	**0-2%**	**3-4%**	**5-7%**	**8-10%**	**>10%**	**Total**
Corn	4,240	2,475	975	710	0	8,399
Soybeans	2,120	2,125	1,150	265	0	5,660
Small grains	530	530	530	0	0	1,590
Forage	0	265	265	0	0	530
Idle	0	265	0	0	0	265
Total	6,890	5,660	2,920	975	0	16,444
Watershed - 05140202 040						
Present crop	**0-2%**	**3-4%**	**5-7%**	**8-10%**	**>10%**	**Total**
Corn	8,339	2,828	324	324	0	11,816
Soybeans	4,624	2,033	1,887	649	0	9,193
Small grains	854	324	649	324	0	2,152
Forage	589	0	0	0	324	914
Idle	854	0	0	0	0	854
Total	15,261	5,186	2,861	1,298	324	24,929

4.2.2 Nonpoint Pollution Loading Estimates

To estimate nonpoint source loadings in the Pigeon Creek tributary watersheds, we reviewed available techniques, selected that most applicable with available resources and applied it. To select a modeling tool for use, we considered:

- Site specific characteristics
- Management objectives
- Available resources

Site-specific features for selecting a watershed model include the constituents of interest (nutrients and solids) and the nature of land use (largely agriculture). Available resources include field data for the sites and the time available to devote to the assessments. The effort to appropriately apply a rigorous watershed model would require several years of data collection and analysis. Because of the desire to have a management tool developed with limited data, a high or mid-level of complexity for the watershed model would not be suitable. We selected the EPA screening procedures, as described by Mills *et al.* (1985) as our nonpoint source estimating tool. The screening procedures can be used to predict sediment and nutrient losses using the Universal Soil Loss Equation (USLE), runoff curve number procedure, and loading functions of agricultural nonpoint loads. Detailed calibration of the watershed model is, in fact, not necessary. Model objectives are to discriminate between tributary watershed and to identify problem areas. The relative results of modeling are more informative than the absolute values.

Sediment loadings to Pigeon Creek were computed for each of the 26 subwatersheds in the study area (Exhibit 10). The EPA's Simple Method for Watershed Sediment Yield was used. Sediment loadings were calculated based on rainfall, land use, and soil type within the subwatershed (EPA, 1985). The watershed sediment yield due to surface erosion is estimated as:

$$Y = s_d \sum_k X_k A_k \qquad \text{Equation (1)}$$

where

$Y =$	annual sediment yield (tons/year)
$X_k =$	erosion from source area k (tons/ha)
$A_k =$	area of source are k (ha)

s_d = watershed sediment delivery ratio

Erosion from each subwatershed was estimated using the Universal Soil Loss Equation (USLE), which is an empirical equation designed to predict average annual soil loss from source areas. The relationship is:

$$X = 1.29(E)(K)(ls)(C)(P) \qquad \text{Equation (2)}$$

where

X = soil loss (t/ha)
E = rainfall/runoff erosivity index (10^2 m-ton-cm/ha-hr)
K = soil erodibility (t/ha per unit of E)
ls = topographic factor
C = cover/management factor
P = supporting practice factor

The erosivity term E is dependent upon rainfall data. Average annual values for the United States are presented in the EPA's Water Quality Assessment (Mills *et al.* 1985). For the Pigeon Creek watershed, the average value is 390.

Soil erodibility (or "K") values are a function of soil texture and organic content. Soil type was identified for each subwatershed (Exhibit 4). The corresponding K values are tabulated below.

Table 28

SOIL ERODIBILITY "K" VALUES
(Source: STATSGO)

Soil Type	Soil ID	K Value
Alford	IN0050	0.37
Fairpoint	OH 0171	0.28
Hosmer	IN00054	0.43
Huntington	WV005	0.37
Peoga	IN0059	0.43
Reesville	OH0014	0.37
Stendal	IN0058	0.37
Wakeland	IN0031	0.37
Wheeling	WV0012	0.37
Zanesville	KY001	0.43
Zipp	IN0055	0.28

The topographic factor, ls, is related to slope angle and slope length by the following relationship:

$$ls = (0.045x)^b (65.41\sin^2\theta + 4.56\sin\theta + 0.065) \qquad \text{Equation (3)}$$

The slope angle θ is obtained from the percent slope, s by:

$$\theta = \tan^{-1}(s/100) \qquad \text{Equation (4)}$$

Slopes of each soil type and the resulting topographic factors are listed below.

Table 29

TOPOGRAPHIC FACTORS

(Source: STATSGO)

Soil Type	Ls
Alford	0.13
Fairpoint	0.29
Hosmer	0.01
Huntington	0.01
Peoga	0.01
Reesville	0.01
Stendal	0.01
Wakeland	0.01
Wheeling	0.01
Zanesville	0.08
Zipp	0.01

The cover/management C factor is a measure of the protection of the soil surface by plant canopy, crops, and mulches. The maximum C value is 1.0, which corresponds to no protection, while a value of 0.0 corresponds to total protection. Published C values were selected from Wischmeier and Smith (1978) are based on the land use type (Table 30). Because C values for impervious areas are zero, this technique underestimates solids loadings from urban runoff.

Table 30

C VALUES FOR LAND USES IN WATERSHED

Land Use	C Value
Other Non-vegetated	0
Urban High Density	0
Urban Low Density	0
Agriculture Row Crop	0.540
Agriculture Pasture/Grassland	0.055
Shrubland	0.055
Woodland	0.055
Forest Deciduous	0.004
Forest Evergreen	0.004
Forest Mixed	0.004
Wetland Forest	0.004
Wetland Woodland	0.055
Wetland Shrubland	0.055
Wetland Herbaceous	0.055
Wetland Sparsely Vegetated	0.067
Water	0

The supporting practice factor P is a measure of the effect of traditional soil conservation practices on erosion from agricultural fields. Purdue's Transect program was used to find P factors for the Pigeon Creek watershed, based on its 11-digit HUC code (Hess 2000). This database provides easy access to information gathered during surveys of agricultural fields throughout the state of Indiana. A value of 1 was recorded for the Pigeon Creek watershed, which corresponds to no conservation practices, and therefore a P factor of 1 was used in the model.

The watershed sediment delivery ratio is a measure of the attenuation of sediment through deposition and filtering as it moves from source areas to the receiving water. EPA (1985) recommends the sediment delivery ratio as a function of the watershed drainage area. Vanoni (1975) published a figure depicting this relationship, and we used this to determine the sediment delivery ratio for each subwatershed. Sediment delivery ratios for the Pigeon Creek subwatersheds ranged from 0.17 to 0.19. The annual sediment yield for each subwatershed was calculated according to Equation 1 and the results are presented below and in Exhibit 21.

Table 31

SUBWATERSHED ANNUAL SEDIMENT YIELD (tons)

Subwatershed	Annual Yield	Area (acres)	Unit Areal Loading (tons/acre)
1. Locust Creek Lower	294	6,101	0.05
2. Locust Creek Headwaters	501	6,497	0.08
3. Kleymeyer Park	9	4,176	0.00
4. Harper Ditch	118	6,544	0.02
5. Crawford Brandeis Ditch	321	5,903	0.05
6. Weinsheimer Ditch	1,559	9,103	0.17
7. Barnes Ditch	759	13,216	0.06
8. Dennis Wagner Ditch	236	4,231	0.06
9. Firlick Creek	205	4,171	0.05
10. Stubbs Fruedenberg Ditch	194	3,911	0.05
11. Schlensker Ditch	377	4,622	0.08
12. Little Pigeon Creek	308	11,209	0.03
13. Unnamed Trib to Bluegrass	370	5,247	0.07
14. Bluegrass Creek Headwaters	448	6,190	0.07
15. Clear Branch	939	14,582	0.06
16. Squaw Creek	846	8,543	0.10
17. Big Creek - Little Creek	878	10,524	0.08
18. Big Creek Headwaters	1,623	11,604	0.14
19. Big Creek – Wye	465	7,117	0.07
20. Smith Fork Headwaters	1,148	14,573	0.08
21. Smith Fork - Halfmoon Cr	832	10,672	0.08
22. Snake Run	1,301	14,449	0.09
23. Hurricane Ditch Creek	2,327	10,420	0.22
24. West Fork Creek	6,712	19,064	0.35
25. Clear Fork Ditch	5,299	11,359	0.47
26. Sand Creek - Muddy Fork	1,643	11,200	0.15
TOTAL	**29,712**	**235,228**	

4.2.3 Phosphorus Loading Modeling

Phosphorus loadings to Pigeon Creek were computed for the study area as well. Again, the EPA's Simple Method for Watershed Particulate Phosphorus was used. Phosphorus loadings were calculated based on the sediment yield, phosphorus concentration in the soil, and the nutrient enrichment ratio (EPA, 1985). The watershed phosphorus yield due to surface erosion is:

$$LS = 0.001\, s_d \sum_k Cs_k X_k A_k \qquad \text{Equation (5)}$$

where

LS = solid-phase chemical load in runoff (kg/ha)
Cs = concentration of chemical in eroded soil (sediment) (mg/kg)
X = soil loss (tons/ha)

The concentration of chemical in eroded soil, Cs, is computed using the following relationship:

$$Cs = en\ Ci \qquad \text{Equation (6)}$$

where

en = nutrient enrichment ratio
Ci = nutrient concentration in *in situ* soil (mg/kg)

Concentrations of phosphorus in the *in situ* soil were not available from the STATSGO database or other available sources, therefore an estimate of the phosphorus concentration was obtained from a general map (EPA, 1985). East central Indiana has a range of percent P_2O_5 as phosphorus of between 0.1 and 0.19 percent. An intermediate value of 0.15 was used. Because 44% of P_2O_5 is phosphorus, Ci is 660 mg/kg.

A nutrient enrichment ratio is a measure of the degree of erosion that occurs during a storm. For an annual phosphorus estimate, as desired for this study, EPA (1985) suggested an enrichment ratio of 2.0. Therefore, the corresponding Cs value is 1,320 mg/kg.

The Cs value is assumed to be the same for all source areas and land types. Therefore, Equation 5 becomes:

$$LS = 0.001\ Cs_k\ s_d \sum_k X_k A_k \qquad \text{Equation (7)}$$

The following results were obtained for each subwatershed (Table 32). As these values are derived from sediment loading estimates, phosphorus loadings from impervious areas are underestimated. The point sources identified in Section 4.1 are not included in this tabulation, as they would be if a Total Maximum Daily Load (TMDL) for phosphorus were being developed.

Exhibit 22 is a map color coding each subwatershed according to its relative contribution of phosphorus to the nonpoint pollution budget. In general, it is similar to the sediment loadings.

Table 32

SUBWATERSHED ANNUAL PHOSPHORUS LOADING (kg)

Subwatershed	Load (kg)	Area (acres)	Unit Areal Loading	
			(kg/acre)	(kg/ha)
1. Locust Creek Lower	388	6,101	0.06	0.16
2. Locust Creek Headwaters	662	6,497	0.10	0.25
3. Kleymeyer Park	12	4,176	0.00	0.02
4. Harper Ditch	156	6,544	0.02	0.06
5. Crawford Brandeis Ditch	424	5,903	0.07	0.18
6. Weinsheimer Ditch	2,058	9,103	0.23	0.56
7. Barnes Ditch	1,002	13,216	0.08	0.19
8. Dennis Wagner Ditch	312	4,231	0.07	0.18
9. Firlick Creek	271	4,171	0.06	0.16
10. Stubbs Fruedenberg Ditch	255	3,911	0.07	0.16
11. Schlensker Ditch	498	4,622	0.11	0.27
12. Little Pigeon Creek	406	11,209	0.04	0.09
13. Unnamed Tri to Bluegrass Cr	488	5,247	0.09	0.23
14. Bluegrass Creek Headwaters	591	6,190	0.10	0.24
15. Clear Branch	1,239	14,582	0.08	0.21
16. Squaw Creek	1,117	8,543	0.13	0.32
17. Big Creek - Little Creek	1,159	10,524	0.11	0.27
18. Big Creek Headwaters	2,142	11,604	0.18	0.46
19. Big Creek – Wye	614	7,117	0.09	0.21
20. Smith Fork Headwaters	1,515	14,573	0.10	0.26
21. Smith Fork - Halfmoon Cr	1,098	10,672	0.10	0.25
22. Snake Run	1,718	14,449	0.12	0.29
23. Hurricane Ditch Creek	3,071	10,420	0.29	0.73
24. West Fork Creek	8,860	19,064	0.46	1.15
25. Clear Fork Ditch	6,994	11,359	0.62	1.52
26. Sand Creek - Muddy Fork D	2,168	11,200	0.19	0.48
TOTAL	**39,218**	**235,228**	**0.17**	**0.41**

5.0 STREAM REACH CHARACTERIZATION AND EVALUATION

Under Indiana's CSO strategy, and required under EWSU's NPDES permit (National Pollutant Discharge Elimination System), combined sewage overflows in the City of Evansville are to be assessed under the protocol for a Stream Reach Characterization and Evaluation Report (SRCER). The SCRER is intended to address the ninth minimum CSO control (IDEM 1996). The IDEM's requirements for a SRCER include the following:

1. A assessment of rainfall events
2. The frequency and duration of wet weather overflows
3. A characterization of the combined sewer system (CSS) and evaluation of the efficacy of implemented CSO controls on receiving waters
4. A list of affected municipalities, sensitive areas and recreational facilities.

This chapter reviews this information and constitutes the EWSU's SCRER.

5.1 CHARACTERIZATION OF THE COMBINED SEWER SYSTEM

An estimated 420 miles of sanitary and combined sewers are operated by EWSU. The sanitary and combined sewer system is divided into 24 separate subsystems each served by a main interceptor sewer or main lift station. Approximately half of the subsystems are combined sewer areas. The subsystems are numbered E-1 through E-12 and W-1 through W-12. The E and W identifiers indicate whether flow is tributary to the Eastside or Westside Wastewater Treatment Plants (WWTP). Exhibit 2 shows the EWSU service area and delineates the subsystems, major interceptors and lift stations and combined sewer overflows and diversion structures.

5.1.1 Subsystem W-1

Subsystem W-1 is served primarily by separate sanitary and storm sewers. There are two major trunk sewers for this subsystem. One is a 12 to 15-inch sewer, which generally flows south along Carpenter Creek to its junction with the force main from the Broadway Avenue Lift Station. The second major trunk sewer is a 18 to 30-inch sewer which flows east along Broadway Avenue to the Broadway Avenue Lift Station. From here, flows are conveyed through a force main to the junction with the Carpenter Creek sewer. To convey the combined flows from the two main trunk sewers, the sewer diameter increases to 36-inches and the storm water flows are added making this section of the sewer a combined sewer. This sewer discharges to the 66-inch sewer from Subsystem W-2 which terminates at the West Treatment Plant. Excess flows in this subsystem are diverted into the Ohio River from the 66 inch combined sewer at CSO#23.

5.1.2 Subsystem W-2

Subsystem W-2 is also served by combined sewers. Many of the sewers in this subsystem are large diameter pipes to obtain the extra capacity required to handle the combined storm and sanitary flows. The major sewer for this subsystem is the Broadway Avenue sewer, a 66-inch sewer flowing south on Broadway Avenue and west to the Westside WWTP.

There are two main trunk sewers in this basin, both discharging to the Broadway avenue interceptor. The St. Joseph Ave trunk sewer terminates at CSO No. 022 where dry weather flows are diverted directly to the Broadway interceptor through a 14-inch throttle pipe and excess flows discharged to the Ohio river. The Ninth Avenue trunk sewer (48 by 60-inch) terminates at Diversion Structure CSO No. 020 where low flows are diverted to the Seventh Avenue Lift Station through a 10-inch throttle pipe and excess flows bypassed to the Ohio River. At the Lift Station flows are combined with discharges from Basin W-3 and other basins and pumped to the Broadway Interceptor through a 42-inch force main.

The Westside Wastewater Treatment Facility and the treatment plant outfall are also located in this subsystem and treated flows are discharged to the Ohio River.

5.1.3 Subsystem W-3

Subsystem W-3 is also served by combined sewers. Many of the sewers in this subsystem are large diameter pipes required to handle the combined storm and sanitary flows. The major sewer for this subsystem is the Pigeon Creek Interceptor, which is a 60-inch to 66-inch sewer, flowing south on Seventh Avenue to the Seventh Avenue Diversion Structure (CSO No. 009). At this structure, a 42- inch throttle pipe serves to divert dry weather flows to the Seventh Avenue Lift Station. From the lift station flows are conveyed to the 66-inch interceptor in subsystem W-2. Excess flows are then diverted to the Ohio River.

There are three additional trunk sewers in this basin that contribute flows to the Pigeon Creek Interceptor. The Delaware Street trunk sewer (48 by 60-inch) adds flows to the Pigeon Creek Interceptor through a 24-inch throttle pipe and bypasses high flows to Pigeon Creek at CSO No. 013.

The Franklin Street trunk sewer (48 by 60-inch) conveys low flows to the Pigeon Creek Interceptor through a 15-inch throttle pipe and bypasses high flows to Pigeon Creek through CSO No. 016.

The Ohio Street trunk sewer (48 by 60-inch) adds low flows to the Pigeon Creek Interceptor through an 18-inch throttle pipe and bypasses high flows to the Ohio River through CSO No. 015.

The Pigeon Creek Interceptor in this basin extends further upstream and also receives flows from subsystems W-4, W-5, W-6, W-7, W-8, W-10

5.1.4 Subsystem W-4

Subsystem W-4 is also served by combined sewers. Many of the sewers in this subsystem are large diameter pipes required to handle the combined storm and sanitary flows. The major sewer for this subsystem is the Pigeon Creek Interceptor, a 30-inch to 60-inch sewer, flowing southwest along Pigeon Creek, west on Ulhorn and Florence, and finally south on Grove Street, where subsystem W-3 begins.

There are five diversion structures/overflows located in this subsystem. These diversions add flows to the Pigeon Creek Interceptor and bypass high flows to Pigeon Creek.

Dresden Street-Fulton Avenue trunk sewer (60 inch) adds low flows to the Pigeon Creek Interceptor through a 15-inch throttle pipe and bypasses high flows to Pigeon Creek through CSO No. 014.

The Baker-Oregon Streets trunk sewer (varies in size from 72-inch to 54-inch) adds low flows to the Pigeon Creek Interceptor through a 24-inch throttle pipe and bypasses high flows to Pigeon Creek through CSO No. 024.

The Read Road trunk sewer (24-inch) adds low flows to the Pigeon Creek Interceptor through a 10-inch throttle pipe and bypasses high flows to Pigeon Creek through CSO No. 024 since CSO No. 026 was eliminated by levee improvements.

The Sixth Avenue trunk sewer (24-inch) adds low flows to the Pigeon Creek Interceptor through a 10-inch throttle pipe and bypasses high flows to Pigeon Creek through CSO No. 017.

The Oakley Street trunk sewer (18-inch) adds low flows to the Pigeon Creek Interceptor through a 12-inch throttle pipe and bypasses high flows to Pigeon Creek through CSO No. 024

5.1.5 Subsystem W- 5

Subsystem W-5 is also served by combined sewers. Many of the sewers in this subsystem are large diameter pipes to obtain the extra capacity required to handle the combined storm and sanitary flows. The major sanitary trunk sewer for this system is an 8 to 27-inch sewer, flowing generally southeast along Golfmoor Road from Wimberg Avenue to Maryland Street. The major combined trunk sewer for this subsystem is a 60-inch by 90-inch special section brick sewer, which flows north on Hess Avenue and then east on Maryland Street to the Maryland Street Diversion Structure. Low flows enter the Pigeon Creek Interceptor into subsystem W-4 through 950-feet of 15-inch sewer. High flows are diverted into Pigeon Creek through the Maryland Street outfall referred to as CSO No. 012.

5.1.6 Subsystem W-6

Subsystem W-6 is also served by combined sewers. Many of the sewers in this subsystem are large diameter pipes required to handle the combined storm and sanitary flows. The major trunk sewer for this system is a 96 to 102-inch sewer, flowing north on Evans Avenue and west on Diamond Avenue to the Diamond Avenue Diversion structure. Low flows enter the Pigeon Creek Interceptor (subsystem W-4). High flows are diverted into Pigeon Creek through CSO No. 025. Subsystems W-10 (via an 18-inch force main from Pfeiffer Road Lift Station) and W-7 are directly tributary to this subsystem.

5.1.7 Subsystem W-7

Subsystem W-7 is also served by combined sewers. Many of the sewers in this subsystem are large diameter pipes required to handle the combined storm and sanitary flows. The major trunk sewer for this system is a 60 to 90-inch sewer flowing north on Fares Avenue, then west on Franklin and finally north on Evans where the sewer connects with subsystem W-6. There are no CSO overflow facilities in W-7. Because subsystem W-7 is tributary to W-6, it contributes to CSO discharges at CSO No. 025 (Diamond Avenue).

5.1.8 Subsystem W-8

Subsystem W-8 is served by separate sanitary and storm sewers. The major trunk sewer for this subsystem is a 15 to 30-inch sewer, which generally flows southeast along an unnamed creek connecting to the Pigeon Creek Interceptor downstream of the Diamond Avenue diversion. There are no CSO overflow facilities in W-8, but it could contribute to combined sewage discharges at CSO No. 025 in subsystem W-6.

5.1.9 Subsystem W-9

Subsystem W-9 is also served by separate sanitary and storm sewers. The major trunk sewer for this subsystem is a 24-inch sewer, which generally flows south along Locust and Pigeon Creek to the Pigeon Creek Interceptor at Grove and Florence Streets in subsystem W-4. Excess flows are diverted into Pigeon Creek through Outfall No. 014.

5.1.10 Subsystem W-10

Subsystem W-10 is also served by separate sanitary and storm sewers. The major trunk sewer for this subsystem is a 30 to 33-inch sewer, which generally flows south along Pigeon Creek to the Pfeiffer Road Lift Station. There are no CSO overflow facilities in W-10. However flows from W-10 are pumped from the Pfeiffer Lift Station into the 102-inch combined sewer serving subsystem W-6. This subsystem therefore can contribute to combined sewage discharges at CSO No. 025 in Subsystem W-6.

5.1.11 Subsystem W-11

Subsystem W-11 is also served by separate sanitary and storm sewers. The major trunk sewer for this subsystem is an 18 to 30-inch sewer, which generally flows south along

Highway 41 to Petersburg Road. Subsystem W-12 is directly tributary to this subsystem. There are no CFO overflow facilities in W-11. Subsystem W-11 is tributary to W-10, which in turn is tributary to W-6 through the Pfeiffer lift station. Therefore subsystem W-11 also contributes to overflows at CSO No. 025.

5.1.12 Subsystem W-12

Subsystem W-12 is served by separate sanitary and storm sewers. The trunk sewer interceptor for this subsystem is a 10 to 15-inch sewer, which flows southwest along Highway 57 to Highway 41. There are no CFO overflow facilities in W-12. Subsystem W-12 is tributary to W-11, which in turn is tributary to W-10 and W-6. Therefore subsystem W-12 also contributes to overflows at CSO No. 025.

5.1.13 Subsystem E-1

Subsystem E-1 is served by combined sewers. Many of the sewers in this subsystem are large diameters pipes to obtain the extra capacity required to handle the combined storm and sanitary flows. The major trunk sewer for this subsystem is the Riverside Drive Interceptor, a 21 to 48-inch sewer flowing southeast on Riverside Drive and Sunset Drive to the Eastside WWTP diversion structure.

There are three diversion structures in this subsystem:

1. The Chestnut Street trunk sewer (48 by 60-inch) adds low flows to the Riverside Drive Interceptor through a 36-inch throttle pipe and bypasses high flows to the Ohio River through CSO No. 008.
2. The Oak Street trunk sewer (48 by 60-inch) adds low flows to the Riverside Drive Interceptor through a 24-inch throttle pipe and bypasses high flows to the Ohio River through CSO No. 038.
3. The Adams Avenue trunk sewer (48 by 60-inch) adds low flows to the Riverside Drive Interceptor through a 24-inch throttle pipe and bypasses high flows to the Ohio River through CSO No. 004.

5.1.14 Subsystem E-2

Subsystem E-2 is served primarily by combined sewers. Many of the sewers in this subsystem are large diameters pipes. The major trunk sewer for this subsystem is the Riverside Drive interceptor, which is a 12 to 21-inch sewer, which flows southeast on Riverside Drive.

There are three diversion structures in this subsystem, which divert high flows to CSO No. 010:

1. The Court Street trunk sewer (48 by 72-inch) adds low flows to the Riverside Drive Interceptor through a 12-inch throttle pipe and bypasses high flows to the Ohio River.
2. The Sycamore Street trunk sewer (48 by 60-inch) adds low flows to the Riverside Drive Interceptor through a 21-inch throttle pipe and bypasses high flows to the Ohio River.
3. The Locust Street trunk sewer adds low flows to the Riverside Drive Interceptor through a 15-inch throttle pipe and bypasses high flows to the Ohio River.

5.1.15 Subsystem E-3

Subsystem E-3 is served by both separate and combined sewer systems. The eastern half of subsystem E-3 is served by separate storm and sanitary sewers. The major sanitary trunk sewer is an 18 to 27-inch sewer flowing generally east along Riverside Drive from Vann Avenue to Gilbert Avenue. Subsystem E-1 accepts flow from E-3 and excess flows in E-1 are bypassed to the Ohio River.

The remainder of the subsystem is served by combined sewers. The first major combined trunk sewer in this subsystem is a 108-inch to 120-inch sewer flowing west on Covert Avenue, then southwest on Wedge Avenue, and finally west on Sweetser Avenue to the Bee Slough Diversion structure.

5.1.16 Subsystem E-4

Subsystem E-4 is served primarily by combined sewers. Consequently, many of the sewers in this subsystem are large diameters pipes. The major trunk sewer for this subsystem is the Garvin-Kentucky trunk sewer, a 66-inch to 96-inch sewer, flowing south on Kentucky Avenue, then west on Monroe Street, south on Garvin Street, and finally west on Cass Avenue into subsystem E-3, where excess flows are bypassed to the Ohio River. E-4 is landlocked so there are no CSO discharges in this subsystem.

5.1.17 Subsystem E-5

Subsystem E-5 is also served primarily by combined sewers. The major trunk sewer for this subsystem is a 54 to 96-inch sewer, known as Covert-Villa trunk sewer, which generally flows south on Villa Drive from Walnut Road, west on Monroe Avenue, flows south on Boeke Road and finally west on Covert Avenue. Subsystem E-6 is directly tributary to this system. There are no CSO facilities in E-5. Subsystem E-7 accepts flows from E-5, which are eventually conveyed through E-3 and E-1 to the Eastside Treatment Plant. Wet weather overflows from this subsystem are eventually discharged to the Ohio River at the Bee Slough Diversion structure in Subsystem E-3.

5.1.18 Subsystem E-6

Subsystem E-6 is served by separate sanitary and storm sewers. The major trunk sewer for this subsystem flows west on Covert Avenue from Audubon Drive to Boeke Road. There are no CSO overflow facilities in E-6. Subsystem E-5 accepts flow from E-6. Wet weather overflows from this subsystem are eventually discharged to the Ohio River in Subsystem E-3.

5.1.19 Subsystem E-7

Subsystem E-7 is served by combined sewers. Many of the sewers in this subsystem are large diameter pipes to obtain the extra capacity required to handle the combined storm and sanitary flows. The major trunk sewer for this system is a 36 to 72- inch sewer, which flows south on Weinbach Avenue to Covert Avenue where the sewer connects with subsystem E-5. There are no CSO facilities in subsystem E-7. Subsystem E-3 accepts flow from E-7. Wet weather overflows from subsystem E-7 are eventually discharged to Bee Slough and the Ohio River via CSO No. 001.

5.1.20 Subsystem E-8

Subsystem E-8 is served by combined sewers. The western quarter of the subsystem however has separate sanitary and storm sewers. The major trunk sewer interceptor for this subsystem is a 27 to 96-inch sewer, which flows west on Division Street and then generally northeast along several streets to the Oakhill Diversion Structure. Excess flows are diverted into Pigeon Creek through CSO No. 011. Dry weather flows from Subsystem E-8 are diverted to the Weinbach lift station from where they are conveyed through a 30 to 36-inch forced main to the main interceptor in subsystem E-3.

5.1.21 Subsystem E-9

Subsystem E-9 is served by separate sanitary and storm sewers. The major trunk sewer for this subsystem is a 15 to 27-inch sewer, which generally flows west on Lincoln Avenue from Martin Lane to Burkhardt Road, then north on Burkhardt, west on Division Street to Stockwell Road, where subsystem E-8 begins. While there are no CFO overflow facilities in E-9, wet weather overflows may occur downstream, such as at CSO No. 011 in subsystem E-8.

5.1.22 Subsystem E-10

Subsystem E-10 is also served by separate sanitary and storm sewers. The major trunk sewer for this subsystem is a 15-inch sewer, which generally flows south along Stockwell Road to the Stockwell Road lift station. Subsystem E-8 also accepts flow from E-10, and wet weather overflows are bypassed to Pigeon Creek through CSO No. 011.

5.1.23 Subsystem E-11

Most of subsystem E-11 is served by separate sanitary and storm sewers. The major trunk sewer for this subsystem is a 15 to 24-inch sewer flowing south along Hitch-Peters Road to Lynch Road. It then flows in a southeastern direction across an agricultural area and begins paralleling Pigeon Creek as it nears the Weinbach Lift Station. It then crosses under the creek to the lift station in subsystem E-7. Other flows converging at this point in E-11 include a 12-inch sewer which acquires flows from the southeastern section of subsystem E-11. There are no CSO facilities located in E-11, but its wet weather flows contribute to E-3, after flowing through subsystem E-7. As inflow and infiltration is kept from entering subsystem E-11, more capacity is available for the 30-inch throttle pipe from Oakhill (CSO 011) to the Weinbach Lift Station.

Three lift stations were eliminated and replaced by a single lift station in this subsystem in 2000.

5.1.24 Subsystem E-12

Subsystem E-12 is served by separate sanitary and storm sewers. The major trunk sewer interceptor for this subsystem is a 21-inch sewer, which flows along Green River Road to Division Street (subsystem E-9). There are two major lift stations that convey flows from E-12 into subsystem E-9, Lakeside Manor and Eagles. While there are no CSO overflow facilities in this subsystem, inflow and infiltration loads can contribute to bypasses at the downstream Oakhill CSO No. 011 in subsystem E-8.

5.1.25 Combined Sewer Overflows and Control Stations

Evansville’s combined sewer system is designed to carry sanitary sewage (consisting of domestic, commercial, and industrial wastewater) and storm water (surface drainage from rainfall or snowmelt) in a single conduit. While the combined sewer system has capacity to carry normal sanitary sewage flows, the amount of storm water entering the system during wet weather events exceeds its capacity. Therefore, to prevent upstream flooding of homes, business and commercial areas, it is general practice to bypass some amount of combined sewage to waterways during wet weather events, while delivering the maximum amount of combined sewage to the treatment plants.

Evansville’s sewer system includes seven CSO control stations discharging to Pigeon Creek. These include:

1. Oakhill Road – CSO 011
2. Maryland Street – CSO 012
3. Delaware Street – CSO 013
4. Dresden Street – CSO 014
5. Franklin Street – CSO 016
6. Baker Street – CSO 024
7. Diamond Avenue – CSO 025

Three additional CSOs facilities contribute combined sewage to Pigeon Creek during wet weather, and consist of simple diversion weirs:

1. 6th Avenue – CSO 017
2. Oakley Street – CSO 018
3. Read Street – CSO 026

The Sixth Avenue and Oakley Street structures divert high flows to Levee Pump Stations. The overflow from diversion structure 018 is directed to the First Avenue Levee Pump Station. The overflow from diversion structure 026 is directed to the outfall of CSO 024 Read Street. These two CSOs were redirected by Army Corp of Engineers Levee projects almost ten years ago.

The operation of the CSO Control Stations to Pigeon Creek is as follows:

Oakhill Road Overflow Control Station (Outfall No. 011). The Oakhill Road overflow control station is located near the intersection of Oakhill Road and Pigeon Creek. This outfall is the farthest upstream overflow point to Pigeon Creek. During wet weather, the large diameter upstream Wesselman Park Interceptor is utilized for termporary storage by allowing it to surcharge. Once the 30-inch throttle pipe between the Control building and Weinbach Lift Station is at full capacity, and the upstream interceptor has surcharged to its maximum allowable level, the outfall gate at the Control Station begins opening. The gate only opens enough to maintain the upstream storage elevation. If the interceptor level continues to rise, the gate continues opening further. This station does not have a gate regulating the throttle pipe (interceptor gate) as most of the other stations do.

The Oakhill CSO bypasses wet weather flows to Pigeon Creek from the following subsystems: E-8, E-9, E-10, E-11 and E-12.

Maryland Street Overflow Control Station (Outfall No. 012). The Maryland Street overflow control station is located just northwest of the Maryland Street bridge over Pigeon Creek. Storage of wet weather flows occurs in the Maryland Street trunk sewer. A 60 by 72-inch sluice gate and a 15 by 15-inch sluice gate regulate overflows to Pigeon

Creek and throttled flows to the downstream W-3 subsystem respectively. The Maryland CSO serves subsystem W-5.

Delaware Street Overflow Control Station (Outfall No. 013). The Delaware Street overflow control station is located near the intersection of Seventh Avenue and Delaware street. Storage of wastewater takes place in the upstream 48 by 60-inch Delaware Street trunk sewer, while a 24 by 24 include sluice gate throttles flow through the 16-inch line connected to the Pigeon Creek Interceptor. Overflows are through a 48 by 60-inch sluice gate to Pigeon Creek. Delaware CSO is one of four CSOs serving subsystem W-3.

Dresden Street Overflow Control Station (Outfall No. 014). The Dresden Street overflow control station is located just west of the intersection of Dresden and Grove Streets. Wastewater storage takes place in the upstream 42 to 60-inch Dresden Street trunk sewer. Flows entering the Pigeon Creek Interceptor are throttled through a 16-inch pipe. The outfall pipe is a sluice gate-controlled 60-inch sewer. Dresden CSO is one of five CSOs located in subsystem W-4. Dresden CSO also serves subsystem W-9.

Franklin Street Overflow Control Station (Outfall No. 016). The Franklin Street overflow control station is located near the intersection of Seventh Avenue and Franklin Street. Storage of wastewater takes place in the upstream 48 by 36-inch and 48 by 60-inch Franklin Street trunk sewer. These flows are throttled through a 16-inch line into the Pigeon Creek Interceptor. Outfall to Pigeon Creek is directed through a 48 by 60-inch sewer. This station is the closest upstream to the 7th Avenue Lift Station-the terminal end of the Pigeon Creek Interceptor. Franklin CSO is one of four CSOs serving subsystem W-3.

Sixth Avenue Overflow (Outfall No. 017). The Sixth Avenue CSO consists of a wooden weir at the downstream end of the Sixth Avenue trunk sewer, a 18 to 24-inch sewer flowing north. Flow into this diversion structure is throttled through a 10-inch line to the Pigeon Creek Interceptor. Although this is not an automated station, the adjacent Levee Pump Station provides high river stage pumping and backflow protection for this CSO. The Sixth Avenue CSO is one of five CSOs serving subsystem W-4.

Oakley Street Overflow (Outfall No. 018). The Oakley Street CSO consists of a wooden weir which diverts dry weather flows to the Pigeon Creek Interceptor via a 12-inch throttle pipe. Wet weather flows are directed to the First Avenue Levee Pump

Station. This pump station provides backflow protection and high river pumping for this overflow.

Baker Street Overflow Control Station (Outfall No. 024). The Baker Street overflow control station is located at the closest approach of Read Street to Pigeon Creek. Storage of wastewater takes place in the Baker Street trunk sewer. This sewer begins at a 48-inch by 72-inch elliptical sewer and ends at the station as a 60-inch reinforced concrete pipe. Dry weather flows are directed to the Pigeon Creek Interceptor by a 24-inch pipe. This pipe has an automated interceptor gate, which has not been needed since levee improvements added a sluice gate to the outfall pipe. When this outfall gate is closed, flows from this station are diverted to the 1st Avenue Levee Pump Station for discharge. Levee improvements also eliminated nearby Read Street CSO, No. 026. The Baker Street CSO is one of five CSOs serving subsystem W-4.

Diamond Avenue Overflow Control Station (Outfall No. 025). The Diamond Avenue control station is located near the crossing of Pigeon Creek with Diamond Avenue. Dry weather flows for this station are diverted toward the southwest by a concrete weir wall, at the intersection of Diamond Avenue and Heidelbach Avenue. A 30-inch throttle pipe from this diversion constitutes the beginning of the Pigeon Creek Interceptor, which increases to 48-inches near Garvin Park/ Richard Street. It flows in a generally southwest direction across Garvin Park. During wet weather, upstream storage is utilized in two trunk sewers of considerable lengths. One is a 60 to 102-inch sewer conveying flows west along Diamond Avenue. The other is a 72 to 96-inch sewer flowing north along Evans Avenue and into the trunk sewer on Diamond Avenue. Outfall flows are via a 102-inch pipe, some distance from the diversion structure. The trunk sewers are surcharged to their maximum volume before the outfall gate is activated to begin opening. No interceptor gate is used on this station because backflow protection is provided by the 1st Avenue Levee Pump Station. The Diamond CSO receives flow from a large service area, including subsystems W-6, W-10, W-11, W-16, and W-7.

Read Road Overflow (Outfall No. 026). The Read Road control station is a diversion structure only, located in the Read Road trunk sewer at Read Road, on the south bank of Pigeon Creek. The outfall was eliminated during construction of levee improvements. The diversion structure still exists. CSO 026 receives flow from the upstream 24-inch Read Street trunk sewer and diverts it through a 10-inch pipe into the nearby Pigeon Creek Interceptor. During wet weather, overflow is directed into the same outfall pipe used by the Baker Street CSO (No. 024). The flow through this structure is minimal during either dry or wet weather flow conditions. This structure serves only subsystem W-4, and is one of five CSOs serving subsystem W-4.

5.2 EVALUATION OF THE NINE MINIMUM CONTROLS

Because CSOs contain untreated domestic, commercial, and industrial wastes, as well as surface runoff, many different types of contaminants can be present. Due to the nature of these contaminants and the volume of overflows, CSOs can cause a variety of adverse impacts on the physical characteristics of surface water, impair the viability of aquatic habitats, and pose a potential threat to drinking water supplies.

Historically, the control of CSOs has proven to be extremely complex. This complexity stems from the difficulty in quantifying CSO impacts on receiving water quality and the site-specific variability in the volume, frequency, and the duration characteristics of CSOs.

To address these challenges, EPA's Office of Water issued a National Combined Sewer Overflow Control Strategy on August 10, 1989 (54 Federal Register 37370). As a part of this CSO strategy, all municipalities with combined sewer systems must practice the nine minimum controls (NMC). These NMC are designed to reduce CSOs and their impacts on receiving water bodies. The NMC as defined by EPA are general in nature and each community must utilize best professional judgment in defining the specific actions to be undertaken by them.

The nine minimum controls are:

1. Proper operation and regular maintenance programs for the sewer system and CSO outfalls
2. Maximum use of the collection system for storage
3. Review and modification of pretreatment requirements to ensure that CSO impacts are minimized
4. Maximization of flow to the POTW for treatment
5. Elimination of CSO discharges during dry weather
6. Control of solid and floatable materials in CSOs
7. Pollution prevention programs to reduce contaminants in CSOs

8. Public notification to ensure that the public receives adequate notification of CSO occurrences and CSO impacts
9. Monitoring to effectively characterize CSO impacts and the efficacy of CSO controls.

The following sections summarize EWSU's efforts to implement the NMC to date:

5.2.1 Control 1: Proper Operation and Regular Maintenance

The first minimum control, 'Proper Operation and Regular Maintenance', of the CSS and CSO outfalls, should consist of a program that clearly establishes operation, maintenance, and inspection procedures to ensure that the CSS and treatment facility will function to maximize treatment of combined sewage and minimize CSOs.

EWSU and the Board of Public Works (BPW) have a number of on-going operation and maintenance activities designed to reduce the frequency and volume of CSO's.

Operational activities include:

- Installation of flow control devices at each of the seven existing outfalls to Pigeon Creek – No. 011 Oakhill, 012 Maryland, 013 Delaware, 014 Dresden, 016 Franklin, 024 Baker, and 025 Diamond. These flow control devices are designed to remain closed and retain all intercepted flows until wastewater levels in upstream sewers exceed critical elevations. This serves to maximize storage in the system and to reduce CSOs.
- Identification of all CSO locations by longitude/latitude, coupled with daily inspection of outfalls. Inspections are intended to determine if dry weather overflows are present.
- Daily inspections of all submerged outfalls to identify whether bypassing is occurring. Inspection reports of these trips are being kept by EWSU.
- An outfall in area W-4 was eliminated and flows rerouted to the Baker (024) outfall.
- In area W-2, a flap gate was installed at the 9th Avenue CSO No. 020 diversion structure during 1997. This prevents river intrusion and maximizes flow to the plant. Also, a new concrete weir wall was pored in this structure. While CSO 020

discharge to the Ohio River, this activity demonstrates EWSU's commitment to system wide implementation of the NMC.

- Renovation of the 7th Avenue lift station to increase the reliability of flow to the Westside WWTP. Also, in second phase of this project, two Roto-Mat screens will be installed to capture floatable materials.
- In area W-1, CSO No. 037 has been eliminated and is not in Evansville's new NPDES permits.
- Identification and numbering of all manholes for effective management and maintenance.

Maintenance activities include:

- A computerized work order system has been developed and implemented which integrates work activities of EWSU and includes maintenance and inspection of existing facilities and allows for data management and record keeping.
- An ongoing program has been established for rehabilitation of sewers and manholes. By 1996, 900 manholes had been repaired by EWSU and to date several sewer subsystems have been rehabilitated including:
    - Area W-7: A Combined Sewer System. The 72-inch to 96-inch larger diameter Evans Avenue sewer north of E. Michigan Street to Diamond Avenue has been rehabilitated.
    - Area W-6: Combined Sewers. The rehabilitation described for W-7 on the Evans Street sewer continued into this sub-system. The 106-inch Diamond Avenue trunk sewer from Evans Avenue to Heidelbach Avenue was replaced with Hobas pipe in 2000.
    - Area E-8: The capacity problem in the 1880 ft of 27-inch sewer located downstream of Stockwell Road (between E-5 and E-9) was eliminated by replacing the sewer with approximately 2,000-ft of 42-inch Hobas pipe in 1999. The volume of combined sewage conveyed westward along the south side of this subsystem will decrease and the large diameter downstream elements in the vicinity of the Oakhill CSO now have increased storage capacity.
    - Area W-5: The city recently completed a storm sewer project on St. Joseph Avenue, west of CSO 012. The new storm sewer will reduce the

wet weather load on this combined trunk sewer along West Maryland Street.

- Area E-9: Approximately 10,500 ft of sanitary lines upstream from the Martin lane lift station were rehabilitated during 1999. Also, a relief sewer for subsystem E-9 was constructed. It provides relief for subsystem E-9, while also impacting E-12 and E-10. This sewer will also decrease the high flows normally conveyed to the Weinbach Lift Station in E-8, and will reduce CSO discharge volumes at the Oakhill outfall No. 011.
- Area E-2: The Riverside Interceptor, a 15-inch sewer beginning at Vine Street, 21-inch sewer at Sycamore, and 27-inch sewer ending at Oak Street, was rehabilitated. Most or all of the special section was brick sewer rehabilitated with Gunite at unspecified times.
- Area E-3: Severe inflow/infiltration problems in this subsystem have been largely eliminated by CIPP rehabilitation of the sewers.

- During 1999, the Pigeon Creek/Weinbach Lift Station Siphon was replaced to improve the hydraulics at this junction. It improved flows to the treatment plant, and reduced CSOs. Extensive reconstruction of the station was performed.
- Several projects designed to prevent backflow from the creek are currently underway. They are at CSOs 002 (Cass), 011 (Oakhill), 013 (Delaware), and 010 (Dress Plaza).

Three lift stations in subsystem E-11 were eliminated in 2000. They were Aspen, Elmridge, and Pleasant Ridge lift stations. The replacement station is referred to as the Lynch Road/Warfield Station. The new station receives flow from the northwest direction. It is then pumped westward to the 15-inch sewer where the Aspen and Elmridge Lift Stations formerly converged.

The siphon where E-11 flows enter E-7 was replaced in 1999. The siphon configuration originally had a chamber on the east bank where the 24-inch and 12-inch sewers from E-11 converged. The chamber then split the flow through 6-inch and 10-inch siphons to another chamber on the west side of the creek. The 30-inch throttle pipe from CSO 011 Oakhill was also tied into this west chamber. The three pipes had to compete for space in the 36-inch line going into the station. In 1999, a new siphon inlet chamber was constructed on the east side of the creek. The chamber accepted the two existing pipes, plus a stub was installed for future additions from E-11. From the new chamber, 14-inch and 20-inch siphons were installed. A new chamber on the west side of the creek accepts flow from these two siphons only, before it is then transported into the station. The 30-inch throttle pipe from Oakhill CSO was rerouted to also enter the station alone. This work removed a hydraulic bottleneck and increased the efficiency of the Weinbach Lift Station.

5.2.2 Control 2: Maximization of Storage in the Collection System

As the second minimum control, the utility is to make maximum use of the collection system for storage. This is to be done through relatively simple modifications to the CSS to enable the system itself to store wet weather flows until downstream sewers and treatments facilities can handle them. This section briefly discusses the measures taken by EWSU to increase the storage capacity of the CSS.

New diversion structures and gate control structures for the seven CSOs along Pigeon Creek were completed in 1980, with renovations in 1990. These control structures include motorized sluice gates on the outfalls to the creek. The gates, which are normally closed, serve to prevent dry weather overflows. However, when influent flows exceed the capacity of the throttle pipes conveying flows to the WWTP, wastewater accumulates in the sewers and the level rises. As the level approaches critical pre-determined values, the gates open automatically to create a CSO and reduce system wastewater levels. This allows EWSU to maximize the use of the sewers for storage.

Maximum system storage is being achieved by insuring that weir heights and gate opening elevations are correct and that the seven automated structures are operating properly. This minimizes pollutants entering receiving waters via CSOs.

5.2.3 Control 3: Review and Modification of Pre-Treatment Programs

Under the third minimum control, the municipality is to determine whether nondomestic sources of sewage, which are subject to pre-treatment requirements, are contributing to CSO impacts, and if so, to investigate ways to control them. The objective of this measure is to minimize the impacts of contaminated discharges into CSSs from non-domestic sources (i.e. industrial and commercial sources, such as restaurants, factories and gas stations), so as to reduce both the volume and adverse impact of CSOs.

Requirements for the pretreatment permit to be obtained by different industries as per the Industrial Pretreatment Ordinance are as follows:

- Monitoring and reporting criteria, including frequency
- Dilution may not be used as a substitute for pretreatment
- Discharges may not exceed limits for cyanide, mercury, methylene chloride, or silver
- Facilities to prevent accidental discharge of prohibited or regulated materials shall be provided or regulated materials shall be provided and maintained by the discharge
- Annual permit fees will be paid by all discharges
- Limits on maximum rate and time of discharge

EWSU is required to develop, enforce and maintain adequate legal authority in its Sewer Use Ordinance to fully implement the pretreatment program in compliance with State and local law. This has been accomplished and EWSU has a successful pretreatment program in place.

The pretreatment program currently in place should be continued. The ordinance covering industrial discharges, which mandates compliance with certain criteria, should be effective in reducing significant pollutants from being introduced into the sewer system. CSO quality monitoring performed under this study included analysis of several heavy metals present in industrial wastewater and did not indicate significant concentrations of those metals.

5.2.4 Control 4: Maximization of flow to the POTW for treatment

The fourth minimum control, maximizing flow to the POTW, entails simple modifications to the CSS and treatment plant to accommodate as much wet weather flow as possible. The objective of this minimum control is to reduce the magnitude, frequency and duration of CSOs by capturing and treating a greater volume of the flows.

There are no known process limitations or bottlenecks at either the Eastside or Westside WWTPs. The Eastside Plant is designed for 18 mgd through the secondary treatment system. The Westside Plant is designed for 20.6 mgd through the secondary treatment system.

Both treatment plants also have primary treatment capacities exceeding their secondary treatment capacities. This means that significantly higher flows of combined sewage can be given primary treatment alone without substantial plant modifications. However, in practice, discharge of wastewater flows after primary treatment alone is not allowed under the current NPDES Permit. The full primary treatment capacity is not being utilized.

The CSS possesses automated CSO structures. These structures were designed with the intent of minimizing CSO discharges by maximizing the storage capacity of the tributary sewers and maintaining maximum flows to the WWTP. This has resulted in a significant volume of combined sewage being retained within the system and conveyed to the treatment plant rather than being discharged without treatment. As a consequence while average flows to the plants were less than the design values, flows treated during rain events have approached the plant capacities (Table 33).

Table 33

AVERAGE INFLOWS TO EASTSIDE AND WESTSIDE WWTPS DURING WET WEATHER

Rainfall Events	Westside WWTP Flow (MGD)	Eastside WWTP Flow (MGD)
02/13/00	19.9	13.8
02/17/00	19.1	14.9
02/21/00	17.7	15.8
02/23/00	16.6	12.6
02/26/00	20.3	15.8
03/01/00	16.1	15.5
03/03/00	16.3	14.6
03/06/00	15.4	12.9
03/07/00	15.1	12.2
03/11/00	14.9	14.2
03/12/00	12.9	14.1
03/13/00	16	11.9
03/16/00	17.2	16.2

Table 33

AVERAGE INFLOWS TO EASTSIDE AND WESTSIDE WWTPS DURING WET WEATHER

Rainfall Events	Westside WWTP Flow (MGD)	Eastside WWTP Flow (MGD)
03/18/00	19	16.4
03/19/00	20.5	17.5
03/20/00	16.8	16.8
03/26/00	17.8	15.6
05/02/00	16.3	11.3
05/03/00	17.5	13.2
05/04/00	15.6	12.6
05/09/00	16	13.2
05/12/00	12.7	11.8
05/17/00	14.4	10.8
05/18/00	15.8	13.1
05/22/00	16	12.4
05/23/00	15.1	14.4
05/26/00	15.2	14.3
05/27/00	13.7	12.6
05/29/00	12.8	8.5
06/02/00	16.7	12.2
06/05/00	15	11.9
06/10/00	12.4	9.7
06/14/00	16.5	12.5
06/16/00	16.7	15
06/17/00	18.3	15.8
06/18/00	18.1	14.4
06/21/00	18.2	14.4
06/24/00	17.7	11.2
06/26/00	19.4	17.6
06/27/00	20	15.9
08/04/00	14.7	9.3

Table 33

AVERAGE INFLOWS TO EASTSIDE AND WESTSIDE WWTPS DURING WET WEATHER

Rainfall Events	Westside WWTP Flow (MGD)	Eastside WWTP Flow (MGD)
08/05/00	12.9	9.9
08/07/00	17.7	13.1
08/08/00	17.2	12
08/18/00	16	12.6
08/23/00	18.7	14.4
08/24/00	17.6	13.7
08/27/00	20.5	16.4

5.2.5 Control 5: Elimination of CSO Discharges During Dry Weather

The fifth minimum control, elimination of CSOs during dry weather, includes any measures taken to ensure that the CSS does not overflow during dry weather flow conditions. Since the NPDES program prohibits dry weather overflows (DWOs), the requirement for DWOs elimination is enforceable independent of any programs for the control of CSOs.

In Evansville, dry weather overflows usually only occur if flows to the treatment plants, (through the throttle pipes) are restricted leading to a build-up of wastewater in the sewers and eventual opening of the gates to Pigeon Creek.

Some potential conditions for dry weather overflows exist in Evansville and particularly at the 9th Ave CSO #020. This outfall discharges into the Ohio River. The reasons for this are:

1. The 10-inch throttle pipe continually fills with sand and rock and requires frequent power flushing to maintain its capacity. This maintenance is difficult because the pipe is parallel to an elevated train track and near a concrete batch plant and a river terminal. This throttle pipe is scheduled for CIPP rehabilitation during 2001.

2. During wet weather, when the 7th Avenue lift station is pumping maximum flow to the Westside WWTP, and upstream surcharging begins, this throttle pipe loses flow velocity, solids settle and the weir at 9th Avenue becomes submerged, resulting in an overflow.

Frequent after storm maintenance is required to protect against such dry weather overflows.

Another risk of DWO has been identified at Maryland CSO 012. The bar screen protecting the 15-inch siphon there must also be cleaned frequently.

5.2.6 Control 6: Control of Solid and Floatable Materials

The sixth minimum control is intended to reduce and possibly eliminate, visible floatable and solids from CSOs using relatively simple measures/devices. Typical devices include baffles, screens, and racks that can be used to remove coarse solids and floatables from combined sewage. Other devices such as booms and skimmer vessels can help remove floatable from the surface of the receiving water body.

Evansville has considered and evaluated a number of measures designed to remove solid and floatable matter (Rust 1997). Recommendations of this report have been considered infeasible have not been implemented. Plans are in place to install two Roto-Mat screens at the 7th Avenue Lift Station as the station is rehabilitated. This upgrade will remove floatables from CSO currently discharging to the Ohio River. Evansville's Long Term Control Plan, now in progress, will identify other feasible projects for solids and floatables control.

5.2.7 Control 7: Pollution Prevention Programs

The seventh minimum control, pollution prevention, is intended to keep contaminants from entering the CSS and thus waters receiving CSOs. The objective of this minimum control is to reduce, to the greatest extent possible, the amount of contaminants that enter the CSS. To meet this objective, in 1995 the EWSU and its contract operator, EMC, implemented a 3-year cycle of cleaning all sanitary and combined sewer lines greater than 24-inch diameter. The program will soon begin its third cycle. This sewer cleaning involves power jetting and vacuuming.

In addition, a number of pollution prevention programs have been initiated in the community by several organizations. Among these are source control programs for street sweeping, public education, solid waste collection and recycling.

Street Cleaning. Browning Ferris Industries, under contract to the EWSU, cleans city streets according to the following schedule:

Business areas:	Weekly
Major Arteries:	Monthly
Residential Areas:	Twice a year.

Public Education Programs. Public education programs can encourage the proper disposal of sanitary and personal hygiene items, which cause the greatest public concerns.

Environmental Management Corporation's (EMC) management staff conducts wastewater treatment plant tours for grade schools, high schools, universities, and other interested groups to teach wastewater's link with the natural hydrologic cycle. In addition, as a part of the Evansville community, EMC participates in community projects that give young people an awareness of issues such as water conservation, water pollution and the importance of water to society.

Evansville Operation City Beautiful (OCB), founded in 1972, works to involve persons in keeping the community clean and healthy by conducting educational programs and seminars.

The web site, http://EA2-Evansville.com/ is dedicated to providing public information of the Evansville Water Filtration Plant, filtration quality control, water distribution system, and water conservation. School and group presentations are offered, along with many national links to websites with water conservation topics.

Solid Waste Collection and Recycling. Evansville's ongoing programs for solid waste collection and recycling reduces litter, advocates reuse of existing resources, and recycling. Institutions involved in solid waste collection and recycling issues and their activities include the Vanderburgh County Solid Waste Management District (VCSWMD) and Browning Ferris Industries.

Through the IDEM funding, citizen and business support, and volunteers, the VCSWMD educates clubs, organizations, and others about resource conservation and recycling of solid waste.

The VCSWMD develops and distributes educational materials to citizens and businesses on waste reduction and recycling, composting, hazardous waste, improper waste disposal and other issues. In addition, VCSWMD also carries out many other activities such as agriculture pesticide container recycling, and the household battery recycling program.

Browning Ferris Industries is also the contract operator for refuse collection and recycling. EWSU manages the contract. Solid waste is picked-up according to the following schedule:

Refuse Pick Up:	Weekly at all residences within the City limits.		
Recyclables:	Paper, cardboard, glass and various classifications of plastic are picked up bi-weekly at all residences within the city limits.		
Yard waste:	Leaves, grass clippings, and sticks are picked up		
		March thru December:	Weekly
		January:	Twice
		February:	Once

ORSANCO. The Ohio River Valley Sanitation Commission (ORSANCO) is an interstate water pollution control agency that was established in 1948. ORSANCO operates programs for water quality, monitoring and assessment, spill response, and detection, pollution control standards, and public information and education. Additional information is available at http://www.orsanco.org/.

Pigeon Creek Greenway Passage. The Greenway, when completed, will cover 42 miles. It follows Pigeon Creek through the center of the city and includes a bicycle/pedestrian trail. Phases I and II were completed in 1997. The Greenway creates a buffer zone along the creek where grass is maintained. It helps in reducing sediment runoff and provides an excellent recreational area with opportunities for environmental education.

In accordance with the State's CSO Strategy, the EWSU has posted signs at CSO outfalls along the Pigeon Creek and the Ohio River. These inform citizens of the pollution potential at each site. A phone number is displayed for notifying the Utility if dry weather discharges are witnessed.

Indiana Department of Environmental Management (IDEM). Through numerous publications, programs, laws and regulations, IDEM provides for pollution prevention and resource conservation in the state of Indiana. Additional information is available at http://www.state.in.us/idem/index.html.

Bulk Refuse Material. Most commercial auto and truck repair shops accept used motor oil and used anti-freeze. These products are then sold to the proper facilities for reprocessing.

Hazardous Waste Collection. Browning Ferris Industries and the VCSWMD collect household hazardous wastes such as paint, pesticides, herbicides, motor oil, anti freeze, tires, unknown chemicals, mercury, lead, and any other hazardous materials. Special days are designated each year. Hazardous waste from business and industry is regulated by the IDEM and the EPA.

Industrial Source Control. The City of Evansville is required to operate a pretreatment program consistent with 327 IAC//5-11 through 5-15. Environmental Management Corporation manages the Pretreatment Lab for EWSU. The lab monitors 29 categorical and 16 non-categorical industries. The program monitors discharge loadings of industrial contaminants and enforces limits on many pollutants. The lab also insures that effluents from Evansville's two wastewater treatment plants are monitored closely and maintained within standards and limits.

Sewer Separation. The City of Evansville has initiated a number of sewer separation projects designed to keep storm water out of combined sewers. One current project is along St. Joseph Avenue in subsystem W-5. This project will reduce wet weather flows bypassed at CSO No. 012 (Maryland Street) through the 60-inch by 84-inch trunk sewer. An existing bottleneck in the throttle pipe siphon at this location will be addressed in Evansville's LTCP.

Another storm water relief project is underway on Weinbach Avenue in subsystem E-7. A 102-inch tunnel is being bored parallel to the existing combination sewer. Street inlets along Weinbach Avenue and storm sewers from adjacent neighborhoods will eventually be routed away from the combined sewer into this new storm line, thus reducing combined sewage flows and overflows.

Similar capital projects have been budgeted to continue improving Evansville's sewer collection system, lift stations, CSO structures, and treatment plants.

Future needs along Evansville's expanding northern corridor are being examined. Lift station upgrades and the need for a new treatment plant are in development. These potential projects would be intended to:

1. Reduce the volume of pollutants discharged at CSOs
2. Increase the sanitary carrying capacity of existing combination piping by removing some of the storm water inflow
3. Decrease the volume of storm water treated at the treatment plants
4. Redistribute flows from overloaded areas to areas with reserve capacity.

5.2.8 Control 8: Proper Public Notification

Evansville has ongoing public notification programs that serve to disseminate information on its wastewater systems. A public meeting will be conducted following the completion of the SRCER on Pigeon Creek. A Citizen Advisory Committee (CAC) will be created to review and give guidance to Evansville's LTCP. The CAC may include representatives from the EWSU Board, City Council, Evansville-Vanderburgh Levee Authority, US Army Corps of Engineers, and the ORSANCO.

Evansville also posted signs at CSO outfalls during December 1999, informing the public about wet weather pollutant discharges.

5.2.9 Control 9: Monitoring Impacts and Efficacy of CSO Controls

This final control involves the monitoring required to characterize CSO impacts and the efficacy of CSO controls implemented under the CSO Operational Plan. The vehicle for this control in Indiana is the Stream Reach Characterization and Evaluation Report (SCRER), included as Chapter 5 of this report. The SCRER also establishes a baseline for evaluating and selecting appropriate long-term CSO controls.

5.3 CSO MONITORING

Rainfall and CSO events were monitored between January 2000 and September 2000. Rainfall events were monitored using an existing rain gauge at CSO No. 025 (Diamond Avenue). The frequency and magnitude of CSO events was monitored using existing measurement equipment at three CSO outfalls, deemed representative of the system. Based upon the characteristics of all permitted CSO outfalls to Pigeon Creek (Exhibit 22), three CSOs were selected for monitoring (Harza 1999):

- CSO No. 011 - Oakhill/Weinbach
- CSO No. 012 – Maryland
- CSO No. 025 - Diamond

ADS Environmental Services, Inc. of Indianapolis provided installation and maintenance services for CSS monitoring equipment. It was intended to use their automatic recording ultrasonic velocity meters and pressure transducers to compute overflow hydrographs. However, quality control questions about data reliability precluded the use of this data. Instead, data from the existing “totalizers” at each outfall were used. These compute daily flow volumes based on hydraulic head and gate opening at each CSO.

Automatic samplers were installed and operated to monitor CSO discharge quality. The automated samplers were installed at CSO Nos. 025 and 011, Diamond and Oakhill. Sampling was initiated manually, with samples taken at 15-minute intervals for two hours, followed by sampling at 30-minute intervals for two hours. Generally, 12 samples were collected over a four-hour period for each monitored wet weather discharge event. This sampling was paired with manual sampling of Pigeon Creek at five locations during the event. Details on sampling and analytical methods may be found in the QAPP (Harza 1999). Laboratory analytical reports are included in Appendix B.

5.3.1 Frequency and Magnitude of Combined Sewer Overflows

During the 8-month monitoring period, cumulative overflow volumes were recorded by the totalizers at CSO Nos. 025, 012, and 011 (Diamond, Maryland, and Oakhill respectively) through the gate just downstream of the diversion point (throttle pipe) to the wastewater treatment plant and the overflow control structure. The volumes measured therefore represented the total overflow and do not include flows to the treatment plant. Exhibits 24 through 26 show the magnitude and frequency of the overflows at the three locations.

Frequency and magnitude of overflows were evaluated based on data collected between January 18, 2000 and August 15, 2000. During this 211-day time period, there was a complete record of overflows for all three locations. EMC staff routinely visit each CSO station daily, except for weekends and holidays, and record the totalizer readings. For the study period, Tables 34 through 36 provide these data for CSO Nos. 025, 012, and 011.

There were 13 CSO events at Oakhill, 37 events at Maryland, and 28 at Diamond during the 211-day period. There were approximately two CSOs per month at Oakhill, five per month at Maryland and about four per month at Diamond. CSO volumes were generally three times greater at Maryland than at Oakhill and twice the CSO volumes at Diamond. The average CSO at Maryland was 43 million gallons, compared to 14 million at Oakhill and 21 million at Diamond.

Table 34

OVERFLOW EVENTS AT OAKHILL

Date	Volume (MG)
02/14/00	7.53
02/22/00	41.60
02/24/00	0.18
02/28/00	12.30
03/16/00	1.41
03/17/00	13.42
03/20/00	1.43
04/10/00	3.95
07/03/00	0.03
07/12/00	78.57
07/19/00	16.51
07/31/00	0.04
08/28/00	3.03

Table 35

OVERFLOW EVENTS AT MARYLAND

Date	Volume (MG)
01/18/00	5.15
02/14/00	26.27
02/18/00	37.57
02/22/00	753.96
02/24/00	202.00
02/28/00	121.63
03/13/00	2.51
03/16/00	29.96
03/17/00	19.28
03/20/00	64.81
03/21/00	1.11

Table 35

OVERFLOW EVENTS AT MARYLAND

Date	Volume (MG)
03/27/00	2.95
04/10/00	62.75
04/28/00	2.01
05/08/00	0.80
05/10/00	0.73
05/15/00	0.30
05/19/00	6.12
05/24/00	4.32
05/30/00	8.92
06/05/00	0.32
06/06/00	0.38
06/15/00	6.26
06/19/00	110.23
06/21/00	12.86
06/26/00	14.56
06/27/00	8.56
06/28/00	1.94
07/03/00	1.86
07/05/00	5.02
07/12/00	0.58
07/19/00	11.76
07/31/00	6.10
08/08/00	3.18
08/09/00	1.22
08/24/00	11.89
08/28/00	25.11

Table 36

OVERFLOW EVENTS AT DIAMOND

Date	Volume (MG)
01/18/00	6.12
02/14/00	20.56
02/18/00	62.21
02/22/00	224.44
02/24/00	47.57
02/28/00	47.55
03/16/00	14.62
03/17/00	15.67
03/24/00	1.00
03/27/00	1.95
04/10/00	20.25
05/19/00	3.67
05/24/00	11.78
05/30/00	4.33
06/19/00	37.70
06/21/00	8.42
06/22/00	3.94
06/26/00	3.27
06/27/00	12.01
06/28/00	1.73
07/05/00	3.16
07/12/00	3.54
07/19/00	6.69
07/31/00	4.37
08/08/00	3.60
08/09/00	4.32
08/24/00	12.06
08/28/00	9.27

These CSO volumes are summarized statistically in Table 37 for all three locations. Clearly one would expect the Maryland CSO to affect Pigeon Creek water quality to a greater degree than the other two outfalls for which we have data. This impact is discussed in greater detail in subsequent sections.

Table 37

CSO VOLUME SUMMARY STATISTICS

	Oakhill	Maryland	Diamond
Minimum	0.03	0.30	1.00
25th percentile	1.41	1.94	3.65
Median	3.95	6.12	7.55
Average	13.85	42.57	21.28
75th percentile	13.42	25.11	16.82
Maximum	78.57	753.96	224.44

Table 38 is a summary of the characteristics of the rainfall events during the sampling period. Three rainfall gages are located in the area: one at Evansville Airport operated by the National Weather Service, another at Newburgh Lock and Dam operated by the U. S. Army Corps of Engineers, and a third installed by the City at the Maryland CSO for this study. Most rainfall events over about 0.25 inches produced some overflow at one of the studied outfalls. The majority of storms occurring during the monitoring period had frequencies of reccurrence greater than six times per year. (Note that a storm with a 2-month recurrence interval is expected to occur at least six times per year). There were however, a number of larger storms with longer recurrence intervals and smaller frequencies. These included 4-month (4/7/00 – 4/8/00), 9-month (6/16/00 – 6/19/00) and 2-year (2/17/00 – 2/19/00) storm events. All of these larger storms tended to produce significant overflows at all locations but especially at Maryland.

Overflow frequency was slightly less at Diamond CSO than at Maryland during the monitored period. In fact, even though storms with frequencies of occurrence greater than the minimum reported 2-month period caused some overflows at Maryland, there were cases where no overflow was observed during such events. Differences in storm duration and intensity were likely responsible for this. Overflows at Oakhill CSO were not as common as the other two monitored sites, although there were some overflow events observed during the monitored period.

Table 38

COMBINED SEWER OVERFLOWS AND RAINFALL EVENTS

Date	CSO (Millons of Gallons)			Rainfall (inches)		
	Oakhill	Maryland	Diamond	Newburgh Lock & Dam	Maryland CSO	Evansville Airport
01/18/00		5.15		0.31	0.10	0.29
02/13/00					1.17	1.43
02/14/00	7.53	26.27	20.56	1.41		
02/17/00				0.48	0.51	0.48
02/18/00		37.57	62.21	0.94	2.97	3.38
02/19/00				1.44		
02/21/00					0.01	0.02
02/22/00	41.60	753.96	224.44	0.08	0.13	0.07
02/23/00					0.43	0.63
02/24/00	0.18	202.00	47.57	0.82	0.32	0.16
02/26/00					1.19	1.09
02/27/00				0.90		
02/28/00	12.30	121.63	47.55			
03/01/00				0.50	0.01	
03/03/00					0.17	0.16
03/11/00				0.38	0.44	0.42
03/12/00				0.38	0.04	
03/13/00		2.51			0.01	0.01
03/16/00	1.41	29.96	14.62	0.51	1.42	1.20
03/17/00	13.42	19.28	15.67	0.76		
03/19/00				0.36	1.14	1.05
03/20/00	1.43	64.81		0.77	0.13	
03/21/00		1.11		0.01		
03/24/00			1.00			
03/26/00					0.04	0.17
03/27/00		2.95	1.95	0.25	0.24	0.11
04/01/00				0.47	0.02	
04/02/00				0.07	0.30	0.26
04/03/00				0.24	0.11	0.19
04/04/00				0.24		
04/07/00					1.29	1.02
04/08/00				0.95		
04/10/00	3.95	62.75	20.25			
04/17/00				0.12	0.05	0.13
04/24/00				0.13	0.45	0.45
04/25/00				0.42		
04/27/00					0.28	0.10
04/28/00		2.01		0.20		
05/02/00				0.22		

Table 38

COMBINED SEWER OVERFLOWS AND RAINFALL EVENTS

Date	CSO (Millons of Gallons)			Rainfall (inches)		
	Oakhill	Maryland	Diamond	Newburgh Lock & Dam	Maryland CSO	Evansville Airport
05/03/00						0.40
05/04/00				0.78		
05/05/00				0.26		
05/08/00		0.80				
05/09/00				0.82	0.18	0.18
05/10/00		0.73				
05/12/00				0.08	0.09	
05/13/00				0.48	0.12	0.14
05/15/00		0.30				
05/18/00					0.41	0.60
05/19/00		6.12	3.67	0.41		
05/20/00				0.20		
05/22/00					0.12	0.27
05/23/00				0.21	0.32	
05/24/00		4.32	11.78	0.46		
05/25/00				0.14	0.10	0.10
05/26/00					0.55	0.48
05/27/00				0.58	0.12	0.12
05/28/00				0.15		
05/30/00		8.92	4.33			
06/02/00					0.11	
06/03/00				0.65		
06/05/00		0.32	0.00		0.09	
06/06/00		0.38	0.00			
06/14/00					0.46	0.49
06/15/00		6.26	0.40		0.11	0.11
06/16/00					1.16	1.44
06/17/00				1.35	1.32	0.82
06/18/00				2.05	0.59	0.53
06/19/00		110.23	37.70	0.41		
06/21/00		12.86	8.42	0.36	0.78	0.56
06/22/00			3.94			
06/24/00				0.25	0.26	0.20

Table 38

COMBINED SEWER OVERFLOWS AND RAINFALL EVENTS

Date	CSO (Millons of Gallons)			Rainfall (inches)		
	Oakhill	Maryland	Diamond	Newburgh Lock & Dam	Maryland CSO	Evansville Airport
06/26/00		14.56	3.27		0.76	1.17
06/27/00		8.56	12.01	1.46	0.61	0.52
06/28/00		1.94	1.73	0.75		
07/03/00	0.03	1.86				
07/04/00				0.63	0.12	
07/05/00		5.02	3.16	0.16	0.53	0.47
07/06/00				0.30		
07/11/00					0.17	1.75
07/12/00	78.57	0.58	3.54	2.07	0.14	
07/18/00					0.06	0.55
07/19/00	16.51	11.76	6.69	0.41	0.69	0.50
07/29/00				0.90	0.87	0.55
07/30/00				0.87		
07/31/00	0.04	6.10	4.37	1.04	0.16	0.11
08/01/00				1.22		
08/03/00						0.36
08/04/00				2.07	0.01	
08/05/00					0.06	0.24
08/07/00					0.42	0.32
08/08/00		3.18	3.60	0.12	0.20	0.38
08/09/00		1.22	4.32			
08/18/00				0.97	0.98	0.79
08/21/00						
08/23/00						1.19
08/24/00		11.89	12.06	1.85	0.73	0.51
08/27/00				0.87		1.74
08/28/00	3.03	25.11	9.27	0.35		

5.3.2 Water Quality Effects

Exhibits 28 through 45 display the results of water quality sample testing undertaken as part of the SCRER. Automated samplers at the Maryland and Diamond CSOs took samples during select events between February and August 2000. Combined sewage samples were analyzed for suspended solids, BOD, *E. coli*, phosphorus, total Kjeldahl nitrogen (TKN), ammonia nitrogen, arsenic, zinc, chromium, copper, lead, cadmium and nickel. Typically, twelve samples were collected at each CSO during an overflow event. During the monitoring period, concurrent surface water samples were also taken. Creek samples were collected manually at five locations once during each sampling events. Creek samples were taken from PC7, upstream of all CSOs, PC4, PC3, PC2 and Highway 62. Laboratory reports are reprinted as Appendix B.

To assess the impacts of the CSOs to water quality, we compared the sampling results to Indiana surface water standards. The exceedances of standards were limited to *E. coli* bacteria (Table 39). The Indiana standard for E. coli is a recreational standard and a maximum at 235, measured as bacteria per 100 mL. Four out of the five storm events we sampled surpassed the *E. coli* limit. Table 39 contains the coliform bacteria data. Sampling station PC7 is upstream of CSOs and reflects nonpoint and point source coliform loadings from the upper watershed. Note that these upstream sources also cause the creek to exceed the state water quality standard. PC4 is downstream of Oakhill CSO and upstream of all other CSOs, including Diamond and Maryland. PC3 is downstream of two more CSOs, including Diamond Avenue. PC2 is located upstream of Dresden CSO (014) as well as Maryland, and downstream of 6^{th} Avenue (CSO 017). The sample at US Highway 62 is near the Ohio River, below all Pigeon Creek CSOs.

Table 39

***E. COLI* CONCENTRATIONS DURING STORM EVENTS**

Storm Event	PC7	PC4	PC3	PC2	Hwy 62
02/13/00	No creek samples collected				
03/16/00	3,100	10	45,000	10,000	23,000
05/23/00	55	15	25	8	28
06/21/00	270	370	1,140	1,710	640
08/08/00	570	510	580	360	240
08/18/00	3,500	27,000	39,900	50,000	17,100

Exhibit 38 displays only wet weather water quality data for Pigeon Creek. Concentrations are plotted against distance from the mouth of the Ohio River. As points of reference, the locations of various CSOs and the Little Pigeon and Locust Creeks are also included.

Phosphorus. Based on the data collected, phosphorus concentrations are relatively constant at all points along Pigeon Creek in the CSO impact area. We generally did not observe more than a 0.3 mg/L fluctuation between sampling points during any given storm event. In all monitored events, there was either no change or a decrease in phosphorus concentrations upstream of the CSOs, as represented by the PC7 sample, or downstream past the Oakhill outfall to PC4. It would therefore appear that the Oakhill CSO has a minor contribution to the watershed's overall phosphorus budget. Downstream of PC4, the Diamond (CSO 025) and Baker (CSO 024) outfalls discharge, contributing pollutants that would have been measured at the PC3 sampling location. In three of the five events, significant increases in phosphorus concentrations were observed at PC3 (Exhibit 39). Typically concentrations were relatively stable or decreased downstream of PC3, at PC2, PC1, and through the final monitoring location at US Highway 62, below all Pigeon Creek CSOs. The state does not have a water quality standard for phosphorus, although nutrient criteria may be developed in the next five years.

BOD. With the exception of the May 23, 2000 event, BOD in Pigeon Creek during wet weather was relatively unaffected by the CSO loads (Exhibit 40). The March 16, 2000 storm event data indicate a dramatic increase between the BOD concentrations at the PC4 and PC7 sampling points. We believe the BOD analysis of the PC7 sample is not representative of instream water quality and may be due to sampling or measurement error. The general BOD trend seems to be one of minor contributions from Evansville's CSOs.

Suspended Solids. While there is substantial noise in the data, the suspended solids concentrations along the waterway seem to be unaffected by the CSO inflows (Exhibit 40). We attribute this noise to the lack of flow-weighted sampling and incomplete mixing downstream of CSOs discharges. During all monitored storm events, TSS levels are high throughout the creek reach we studied, including PC7, upstream of the CSOs. The data do not provide clear evidence for an adverse effect of Evansville's CSOs.

Maryland and Diamond CSO subsystems serve areas considered to be at different levels of risk for soil erosion. Diamond subsystem has a high rating for soil erosion and potential solids and floatables impacts (Exhibit 23), but Maryland has a low potential for soil erosion (but high potential for potential solids and floatables impacts). Peak concentrations in the combined sewage of the two CSOs were similar, although Maryland's was typically slightly higher than that found in Diamond Avenue sewage (Exhibit 27).

E. coli. As discussed earlier, the *E. coli* concentrations (measured per 100 mL) are consistently high during all except the May 23, 2000 storm event and over the entire distance of the creek (Exhibit 38). There is often an increase in *E. coli* concentrations going from the first data point at PC7 to PC4. This increase occurs in two out of the five storm events. In addition, aside from some variation, the general trend downstream is for the *E. coli* concentration to increase. Even when there are decreases within the data, the *E. coli* levels are higher than the recreational water quality standard. There is a frequent increase from PC4 downstream to PC3 in *E. coli* concentration, suggesting that the Baker Street (CSO 024) and/or Diamond Avenue (CSO 025) have compounding effects on receiving water quality.

Exhibit 28 displays the *E. coli* concentrations of combined sewage samples taken at Maryland and Diamond CSOs. Generally the two locations have concentrations in the same order of magnitude.

Historically, concentrations of *E. coli* in Pigeon Creek have commonly exceeded the state's standard, both upstream and downstream of the CSO area of influence. There are point and/or nonpoint sources of coliforms upstream of Evansville that contaminate the stream (Exhibit 7), confirmed by watershed sampling (Tables 14 and 39, Exhibit 38).

Ammonia Nitrogen. Exhibit 42 displays the ammonia nitrogen concentrations for all of the storm events. Creek concentrations reach no more than 4 mg/L in any storm event. Instream temperature and pH measurements were not taken, so the concentration of ammonium ion cannot be estimated properly. Ammonia nitrogen concentrations generally decrease over the stretch of the sampling area.

Total Kjeldahl Nitrogen (TKN). The TKN data also contain a considerable amount of noise (Exhibit 43). Because of this, it is difficult to draw conclusions regarding the impact of the CSOs on TKN. In four out of five events, increases in TKN concentration were observed downstream of PC7, but, by Hwy 62, may return to the levels found upstream (at PC7).

Nitrate Nitrogen. Nitrate concentrations exhibit less fluctuation along the CSO-affected stretch of the creek. The largest change in concentration from one sampling point to the next was 0.8 mg/L, with the other fluctuations being well below that. We conclude that the nitrate loads from the CSOs and streams do not significantly affect the instream nitrate concentrations.

Metals. The Maryland CSO subsystem serves an area of moderate residential population, moderate industrial development, with a low risk of a hazardous material spill (Exhibit 23). Diamond CSO subsystem serves an area of relatively moderate residential population, relatively high industrial development, with a high risk of a hazardous material spill. We monitored several heavy metals in the two CSOs. Arsenic concentrations were similar in Diamond and Maryland discharges (Exhibit 33). In no cases was arsenic in the CSO discharge measured to exceed acute aquatic criteria in 327 IAC 2-1-6, assuming 100 mg $CaCO_3$/L hardness.

Maximum zinc concentrations were 0.5 mg/L in each of the two monitored CSOs (Exhibit 34). Again, assuming 100 mg/L hardness, we observed two samples to exceed the zinc acute aquatic criteria in 312 IAC 2-1-6.

In four of five discharge events, maximum chromium and copper concentrations in Maryland were higher than Diamond (Exhibits 35 and 36, respectfully). Chromium in the CSO discharge was not measured to exceed the State's acute aquatic standards in either outfall, however copper values did in both.

For lead, Diamond CSO exhibited higher concentrations than Maryland (Exhibit 37), and exceeded the acute aquatic critera. Maryland discharge was not measured to exceed th lead acute aquatic criteria. Nickel concentrations were similar in the two discharges (Exhibit 38), and were well below the criteria.

5.4 MUNICIPALITIES, SENSITIVE AREAS AND RECREATIONAL FACILITIES

Federal and state CSO policies require that the highest priorities be given to controlling overflows to waterways in sensitive areas. Therefore, as part of developing the long-term control plan, the EWSU is expected to identify all sensitive waterbodies and the CSO outfalls that discharge to them. Sensitive areas have been defined by the US EPA as:

- Outstanding National Resource Waters
- National Marine Sanctuaries
- Waters with threatened or endangered species or their designated critical habitats
- Primary contact recreation waters, such as bathing beaches,
- Public drinking water intakes or their designated protection areas, and,
- Shellfish beds

The State of Indiana only recently defined outstanding national resource waters (SEA, Section 17, adds IC 13-18-3-2(d) effective July 1, 2000) and none are yet designated in the study area or Ohio River. There are also no national marine sanctuaries in the study area.

Recorded sightings of threatened or endangered species or their critical habitat, as provided to us by the DNR Division of Nature Preserves, are shown on Exhibit 8. The only recording of a state or federally listed species occurring in the Pigeon Creek floodplain downstream of the Oakhill discharge (CSO #011) is the hellbender, a giant aquatic salamander. Hellbender is a state-listed endangered species. Hellbenders prefer clear fast-flowing streams and rivers with rocky bottoms (Behler and King 1998). They are reclusive, hiding under rocks, feeding on macroinvertebrates. Pigeon Creek in Evansville is generally sluggish and turbid with a silt, sand or gravel bottom. There is no date in DNR's database for the last sighting of hellbenders in Evansville. Even with elimination of CSO discharges, Pigeon Creek will remain sluggish and turbid due to its low gradient, backwater effects of the Ohio River, and nonpoint pollution sources of siltation from upstream areas.

There are no primary contact recreation waters in that portion of Pigeon Creek within the CSO area of influence. Heidelbach canoe launch is located on Pigeon Creek approximately two miles downstream of the Oakhill discharge (CSO #011). Canoeing is secondary contact recreation, and would not be expected to occur during or shortly after a storm event. Also the Pigeon Creek Greenway starts at the Heidelbach canoe launch and continues downstream to the Ohio River. The Greenway trail is separated from Pigeon Creek by a minimum 50 to 100-foot wide forest or prairie buffer and steep muddy banks. Similarly the Greenway is not typically used during or shortly after storms, and, the muddy banks and forest buffer provide a barrier discouraging contact with the creek. The entire reach of Pigeon Creek affected by CSO discharges is signed by EWSU to caution users against contact recreation after wet weather.

There are no public water intakes in the Pigeon Creek CSO area. The City of Evansville's intake is in the Ohio River, upstream of Pigeon Creek, north of Sunset Park.

Pigeon Creek harbors freshwater mussels. There are no shellfish beds that are harvested for food there, which is EPA's general regulatory focus. Freshwater mussels are threatened nationally due to water quality and habitat degradation. The CSOs are an example of water quality degradation, but no threatened or endangered species of mussels are recorded for this area.

Seveal locations along Pigeon Creek that may fit IDEM's "priority area" designation are the Hiedelbach Canoe Launch, Kleymeyer Park, Garvin Park, and Nut Club Field. These areas should be given priority attention in the city's long-term CSO control plan.

5.5 CONCLUSIONS AND RECOMMENDATIONS

The data collected as part of this study has served to confirm that there are frequent combined sewage overflows from the Evansville sewer system. There is very little baseline data available on Evansville's CSOs. It is therefore difficult to quantify what decrease in frequency and magnitude of CSO discharges have occurred by implementation of the nine minimum controls. The seven automated control structures constructed in 1980 and upgraded in 1990 undoubtedly reduce the frequency and volume of discharges from the largest Pigeon Creek CSOs. Many collection system and treatment plant projects in recent years have also helped reduce overflows. Sewer separation and inflow and infiltration projects planned and in-progress are helping lessen CSO loadings. Forthcoming Phase II Storm Water Regulations will also eventually aid in CSO reduction. Environmental education efforts will also expand as the LTCP elements are completed.

This report recommends several courses of action be taken to directly and indirectly reduce CSO discharges to Pigeon Creek. Those recommendations include development of a monitoring and modeling plan, continued sewer separation, increasing primary treatment at the wastewater plants (when approved by the IDEM), continued inflow and infiltration reduction efforts, inline storage projects, and a runoff control program. The LTCP, which has been initiated, will consider the feasibility of these and additional technology-based CSO controls.

Evansville, as all other CSO municipalities in Indiana, will be required to develop a technically feasible, affordable, and comprehensive LTCP consistent with the CSO Control Policy. That Policy is intended to document how and when a community will meet the Clean Water Act requirements. The two main methods to demonstrate compliance were the Demonstration and the Presumption Approaches.

The Presumption Approach requires that the LTCP implementation will result in:

- No more than an average of four overflow events a year
- The elimination or capture of no less than 85% by volume of the combined sewage collected in the CSS during precipitation events on a system-wide annual average basis
- The elimination or removal of no less than the mass of the pollutants identified as causing water quality impairment through the sewer system characterization, monitoring, and modeling effort for the volumes that would be eliminated or captured for treatment

Computer modeling during the LTCP will estimate the reduction in overflow volume that the seven automated structures have created since their construction. However, it is unlikely that the Presumption Approach will suffice on Pigeon Creek due to the criteria of no more than an average of four overflow events yearly. The Demonstration Approach requires successfully demonstrating compliance with the following criteria:

- The planned control program is adequate to meet water quality standards and protect designated uses, unless standards or uses cannot be met as a result of natural background conditions or pollution sources other than CSOs
- The CSO discharges remaining after implementation of the planned control program will not preclude attainment of water quality standards or the receiving waters designated uses or contribute to their impairment
- The planned control plan will provide the maximum pollution reduction benefits reasonably attainable, and
- The planned control program is designed to allow cost-effective expansion or cost-effective retrofitting if additional controls become necessary to meet standards or designated uses

Consequently, as part of this study, we have attempted to indicate if Evansville can demonstrate that it meets the water quality based objectives of the Clean Water Act through use of the Demonstration Approach.

In addition to these two approaches to CSO control, the State of Indiana is presently developing guidance for the creation of CSO controls that are practical and cost-effective. Senate enrolled Act 431, signed into law on March 17, 2000, requires the IDEM to develop guidance for Combined Sewer municipalities on how to comply with the Act. More specifically, the guidance will detail the process and procedures with which municipalities must comply in order to develop and submit a LTCP and an Use Attainability Analysis that may be approved by IDEM and the EPA.

The provisions of SEA 431 authorize the temporary suspension of designated uses and associated water quality criteria, provided certain requirements are met. An Use Attainability Analysis (UAA) is a structured scientific assessment of the physical, chemical, biological, and economic factors affecting the attainment of a designated use as defined in 40CFR 131.3(g). The UAA provides a process by which a CSO community may demonstrate that a designated use is not attainable and may obtain a temporary suspension of that designated use. Much of the information required in the UAA is the same as what is required in the LTCP; therefore, IDEM will use the approved LTCP as much as possible to satisfy the requirements of the UAA.

It should be noted that the guidance for these requirements is presently being created. The eventual outcome should be a more realistic approach to CSO controls.

Evansville's LTCP and UAA will determine exactly which route best serves both pollution prevention and fiscal responsibility. As a component of this Pigeon Creek Watershed Diagnostic Study, the SRCER for Pigeon Creek is included. The broad scope of this watershed analysis actually includes more information than required by the SRCER. The data acquired for the chemical, physical, and biological health of the watershed should benefit all parties involved. Evansville will probably find that a combination of the Demonstration Approach and the provisions of SEA 431 will be the best method of CSO reduction.

From the available water quality data, we can confirm that Pigeon Creek is affected by CSO discharges of *E. coli* bacteria and that this water quality standard is regularly exceeded during wet weather. No other water quality standards, as monitored as part of this study, are conclusively and adversely impacted by the CSOs.

Historic concentrations of *E. coli* in Pigeon Creek have commonly exceeded the state's standard, both upstream and downstream of the CSO area of influence. There are point and/or nonpoint sources of coliforms upstream of Evansville that contaminate the stream, confirmed by our sampling (Tables 14 and 39, Exhibits 7 and 38).

Despite this relatively minor impact of CSO's discharges to water quality in Pigeon Creek, there are still a number of measures that EWSU should continue to optimize the operation of the sewer system and further reduce CSO's and their adverse impacts on water quality in Pigeon Creek. Recommended measures are as follows:

5.5.1 Monitoring and Modeling Plan

EWSU should continue development of a Monitoring and Modeling Plan as part of the LTCP for the sewer system. This will assist the Utility in developing a full understanding of the sewer system, its response to various precipitation events, and the characteristics of the overflows. The monitoring program will also serve to confirm the findings of this study and help establish the effectiveness of the CSO controls implemented to date.

Using the model, hydraulic restrictions in the system could be eliminated if flow monitoring work verifies modeling parameters. Specifically, restrictions in throttle pipes at CSOs 009, 012, 016 and 025, which may be at or near their capacity, should be investigated. If upsizing of throttle pipes is warranted, further study of capacity remaining in the Pigeon Creek Interceptor may be necessary.

5.5.2 Continued Sewer Separation

EWSU currently operates both separate sanitary and combined sewers in the various subsystems. However, in a number of cases, separate sanitary sewers discharge to downstream combined sewers for conveyance of the wastewater to the two treatment plants. For example, the Pfeiffer pump station discharges sanitary sewage for Basin W10 into the 102" CS in Basin W6. This discharge is upstream of Diamond CSO (025) on the 102" line. Consequently, during precipitation events, this sanitary sewage is contributing to the overflows or may in fact be the cause of the overflow.

The recommendation now is for EWSU to review options for keeping the sanitary sewage separate from the combined sewers. This can be done by installing a separate sanitary interceptor line that terminates at one of the two wastewater treatment plants. This objective may also be achieved by investigating measures that will allow sanitary sewage to be given priority for discharge into the existing combined sewer interceptors, such as the Pigeon Creek Interceptor. The objective of either of these approaches will be to remove separate sanitary sewage from combined sewage overflows, thus changing the characteristics of such overflows and improving water quality.

It is our understanding that a third treatment plant has been proposed for Evansville and that, thus far, much of the separately sewered areas will be diverted to this new plant. A decision to proceed in this manner will be fully compatible with this approach and will achieve the objective of keeping separate sewage out of the combined sewers.

5.5.3 Treatment Plant Operation

EWSU should approach IDEM with a request for utilizing the existing unused primary treatment capacity at the treatment plants during wet weather. This will allow EWSU to capture and treat a greater percentage of the flows and reduce overflows of untreated combined sewage.

In order to implement such actions, EWSU must also review the capacity of its conveyance system to the plants, and determine whether there is sufficient sewer capacity to deliver the larger flows to the WWTPs. If not, EWSU must review options for increasing sewer capacity to be able to maximize primary treatment at the plants.

5.5.4 Inflow and Infiltration Reductions

It is recommended that all commercial and industrial structures be inspected to identify all sources of inflow and infiltration to the sewer system. Efforts should be made to disconnect such direct sources of inflow, such as downspouts, as much as possible.

The inflow/infiltration monitoring program should be expanded in the combined sewer system. As problems are identified, they should be corrected.

5.5.5 Inline Storage

A gate control system, which would control the non-automated CSOs to Pigeon Creek and the Ohio River, would allow the storage of combined sewerage in the interceptors tributary to the diversions. This gate control system could provide about 154,5000 cubic feet (11.6 MG) of storage. To obtain the full amount of storage, available, additional weirs, gates, etc. may be necessary. A study to investigate the feasibility of such a system, and the condition of the sewers at the storage sites (to avoid damage from surcharging) is warranted. This option will be further investigated during development of the LTCP.

5.5.6 Runoff Control Program

Evaluation of a runoff control program to store and control runoff before it enters the combined system is also recommended. The feasibility and effectiveness of this alterative and others requires development of a system model, scheduled for completion as part of the LTCP.

5.5.7 LTCP

EWSU has retained a consultant to develop a long-term CSO control plan (LTCP) for their sewer service area. The LTCP will include the following elements:

1. The LTCP must be consistent with the federal CSO Policy (58 Fed. Reg. 18688). The LTCP must be approved by the IDEM and ultimately implemented by the CSO community according to a schedule determined by the IDEM.
2. The LTCP must be developed with public participation, using a process designed to promote active involvement by the affected public.
3. The LTCP must use characterization, monitoring and modeling of the combined sewer system to determine:
    a. the response of the combined sewer system to various precipitation events;
    b. the characteristics of the overflows from the combined sewer system (volume and pollutants), and
    c. the water quality impacts that result from the overflows
4. The LTCP must contain an evaluation of a reasonable range of control alternatives, taking into account expected and projected future growth.
5. The LTCP must consider the impact of CSOs on sensitive areas and give highest priority to controlling overflows in those areas.
6. The LTCP must contain cost and performance analysis of the control alternatives evaluated.
7. The LTCP must maximize treatment of wet weather flows at the treatment plant.
8. The LTCP must contain a practical implementation schedule for the selected control alternative.
9. The LTCP must contain a post-construction compliance monitoring program adequate to ascertain:
    a. the effectiveness of the selected control alternative; and
    b. the extent to which water quality standards have been attained.

6.0 WATERSHED MANAGEMENT

This chapter summarizes our knowledge about each subwatershed, contrasts their overall health and pollution sources, and lays the foundation for a watershed management plan for each subbasin.

6.1 BIOTIC AND ABIOTIC RELATIONSHIPS

For many years, researchers (e.g. Omernik 1976) have known that land use and stream nutrient concentrations were related. Biotic indictors have also been shown to correlate with land use, physical habitat or water quality. We subjected the biotic and abiotic data generated in this study to statistical analysis to determine if these relationships held locally, and, to aid in the determination of priorities for pollution reduction investments. Pearson product-moment correlation coefficients were calculated for each of the major land use types as a function of biotic and abiotic data. Correlation coefficients are an estimate for the presence or absence of a linear relationship between the variables. A correlation coefficient with a high absolute value means that upstream land use is more likely to affect the biotic or abiotic variable. The effect may be positive or negative. The reader is cautioned against inferring a cause and effect relationship when observing a correlation. Causality has not been determined experimentally in this study.

Input data for the correlation analysis was developed from land use data (Exhibit 6), nonpoint source loadings estimates (Chapter 4) and the bioassessment data (Chapter 3). Because some subwatersheds contained more than one bioassessment site, we selected one site to represent that subwatershed (Table 40). Twenty subwatersheds were included in this analysis. Similar land use types were combined prior to correlation analysis.

The input data for the correlation analysis allowed for 18 degrees of freedom. Therefore statistical significance at the $P \leq 0.05$ level requires a correlation coefficient with an absolute value greater than 0.444. Statistical significance at the $P \leq 0.01$ level required a correlation coefficient with an absolute value greater than 0.561.

Exhibit 46 and Table 41 present correlation coefficients from our analysis. We found only three statistically significant correlations between subwatershed land use and a biological variable measured in the field. Total drainage area and wetlands area tributary

Table 40
SELECTION OF REPRESENTATIVE BIOASSESSMENT SITES

No	Subwatershed Name	Sampling Sites	Selected Site	Rationale
26	Sand Creek-Muddy Fork Ditch	SA1	SA1	Single subwatershed sample
25	Pigeon Creek-Clear Fork Ditch	PC16, PC15, PC14	PC14	Reflects cumulative upstream uses
23	Hurricane Creek Ditch	HC1	HC1	Single subwatershed sample
24	West Fork Creek	WF3, WF2, WF1	WF1	Reflects cumulative upstream uses
22	Pigeon Creek-Snake Run	None	N/a	
20	Smith Fork-Headwaters	SF3, SF2	SF2	Reflects cumulative upstream uses
21	Smith Fork-Halfmoon Creek	SF1	SF1	Single subwatershed sample
18	Big Creek-Headwaters (Warrick)	None	N/a	
17	Big Creek-Little Creek/Plum Branch	BG2	BG2	Single subwatershed sample
19	Big Creek-Wye In RR	BG1	BG1	Single subwatershed sample
15	Pigeon Creek-Clear Branch	PC13, PC12, PC11	PC11	Reflects cumulative upstream uses
16	Squaw Creek	SC1	SC1	Single subwatershed sample
6	Weinsheimer Ditch	None	WD1	Sample is very near boundary and reflects subwatershed uses
7	Pigeon Creek-Barnes Ditch	UN1, PC9, WD1, SD1, UN1	PC9	Reflects cumulative upstream uses
5	Pigeon Creek-Crawford Brandeis Ditch	PC8	PC8	Single subwatershed sample
14	Bluegrass Creek-Headwaters	None	N/a	
13	Unnamed Tributary (Blue Grass Ck)	None	N/a	
10	Bluegrass Creek-Stubbs Fruedenberg	BC3	BC3	Single subwatershed sample
11	Schlensker Ditch	None	N/a	
8	Bluegrass Creek-Dennis Wagner Ditch	BC2	BC1	Sample is very near boundary and reflects subwatershed uses
9	Bluegrass Creek-Firlick Creek	BC1	BC1	Single subwatershed sample
4	Pigeon Creek-Harper Ditch	PC7, PC6	PC7	Reflects cumulative upstream uses
12	Little Pigeon Creek	LP1, LP2	LP1	Single subwatershed sample
3	Pigeon Creek-Kleymeyer Park	PC5, PC4, PC3, PC2	PC2	Reflects cumulative upstream uses
2	Locust Creek-Headwaters	LC2	N/a	Not representative of overall subwatershed uses
1	Pigeon Creek-Locust Creek (lower)	LC1, PC1	LC1	Reflects cumulative upstream uses

Table 41

PEARSON'S PRODUCT-MOMENT CORRELATION COEFFICIENTS

	Other Non-vegetated	Urban	Row Crop	Pasture	Undisturbed Upland	Wetlands	Drainage Area	Areal Sediment Loading
Other Non-vegetated	1							
Urban	-0.1435	1						
Row Crop	-0.5634	-0.3108	1					
Pasture	0.6497	-0.0682	-0.8268	1				
Undisturbed Uplands	0.3254	0.5126	-0.8873	0.4955	1			
Wetlands	0.2872	-0.2770	-0.6616	0.6767	0.4349	1		
Drainage area	-0.1302	-0.0707	0.1229	-0.1705	-0.1825	0.2948	1	
Areal sediment loading	-0.3759	-0.3571	0.1290	0.0562	-0.2551	0.3876	0.0831	1
FBI (Aug)	0.0906	-0.0204	-0.0144	0.1145	0.0084	-0.2063	-0.4143	0.0648
FBI (May)	0.2940	-0.2630	0.0913	0.2045	-0.3409	0.0220	0.2277	0.0171
Scrapers (Aug)	0.1667	0.0890	0.1702	-0.1710	-0.0825	-0.4974	-0.4735	-0.4195
Scrapers (May)	0.3326	-0.1158	0.1998	-0.1802	-0.2249	-0.2165	0.2589	-0.3354
Filterers (Aug)	0.2179	0.2113	-0.3345	0.3233	0.2208	0.2180	0.0302	-0.0410
Filterers (May)	-0.2190	-0.3630	0.2405	-0.2189	-0.1256	-0.0599	-0.2650	0.1258
Taxa Richness (Aug)	0.1276	-0.0976	-0.0593	-0.0211	0.0944	0.1033	-0.1846	0.1752
Taxa Richness (May)	0.2439	-0.5073	0.0885	0.0345	-0.2029	0.2421	0.1580	0.1885
EPT (Aug)	-0.0243	-0.0660	0.2902	-0.2396	-0.2974	-0.1981	0.0369	0.1239
EPT (May)	0.1193	0.0514	-0.2316	0.1046	0.2548	0.2200	-0.2312	0.0440
Chironomids (Aug)	-0.2627	-0.2247	0.4201	-0.3686	-0.3390	-0.2309	0.1788	-0.0905
Chironomids (May)	-0.4027	0.0466	0.3151	-0.3482	-0.2038	-0.2045	0.2291	-0.0289
% Dominance (Aug)	-0.1072	0.0443	0.2869	-0.3324	-0.2428	-0.1756	0.3687	-0.0732
% Dominance (May)	-0.2402	0.2944	-0.0454	0.0070	0.0760	-0.0582	0.0925	-0.0573
Shredders (Aug)	0.0041	0.2254	-0.1696	0.1154	0.0888	0.2321	0.4155	0.0087
Shredders (May)	0.1358	-0.2332	0.0048	0.2068	-0.2050	0.1897	0.0080	0.0797
Silt (Aug)	-0.0549	0.1640	0.0055	0.0656	-0.0918	-0.0208	0.4153	-0.2409
Silt (May)	-0.0089	0.0071	0.4069	-0.4028	-0.3709	-0.3584	0.2063	-0.0990
Substrate (Aug)	-0.0474	-0.3052	0.0290	0.1048	-0.0665	0.0881	-0.3601	0.3074
Substrate (May)	0.0252	-0.4877	0.0132	0.2122	-0.0917	0.1249	-0.5222	0.2941
Average QHEI Score	0.3196	-0.1649	-0.6643	0.6993	0.4956	0.7116	-0.0893	0.2375

Notes:

(light shading)	There is at least a 95% chance of a statistically significant linear relationship between these two variables.
(dark shading)	There is at least a 99% chance of a statistically significant linear relationship between these two variables.

to a sampling site were each found to be negatively correlated to the relative abundance of the scraper feeding group (as sampled in August). Scrapers are those benthic organisms that obtain their nutrition by scraping algae from the substrate, and include snails and the Heptageniidae mayflies. The presence of large numbers of scrapers may be indicative of a habitat with excess periphyton. Scrapers also tend to increase with an abundance of diatoms. As our correlation coefficients were negative, this implies that subwatersheds with large drainage areas or with a significant portion of its drain as wetland, relatively few scrapers were found in August. This correlation was not significant for the May data set. Our findings are not inconsistent with those of Lenat (1984), who in his studies of North Carolinian watersheds, concluded that scrapers are one of the benthic feeding guilds that should be favored by agricultural development and the associated stimulation of periphyton. We simply were unable to correlate agricultural development with scraper abundance.

The third correlation found was a negative relationship between the relative extent of urbanization and the richness of the benthic fauna during May. No significant correlation exists for taxa richness in August.

We found few case studies in the literature offering similar analyses relating catchment scale land use and cover to macroinvertebrate community variables. Lammert and Allan's 1999 publication of their studies in a Michigan watershed found benthic measures to correlate well with 100-m and 250-m riparian buffer zone land use/cover. But, like us, they were not able to correlate biotic measures with catchment scale land use/cover. In their study of central Michigan streams, Richards *et al.* (1996) found macroinvertebrate communities to be regulated by habitat and channel morphology, which in turn are influenced by watershed geology and land use. The ability to detect biotic-abiotic correlations depends on the range of conditions within the variables measured. This suggests that our study may have been improved by the addition of high quality, relatively undisturbed subwatersheds. These do not occur in the Pigeon Creek watershed, and are very rare in the state of Indiana.

We also found six statistically significant correlations between catchment land use and local physical habitat quality. The substrate score, as assessed in May, shows a significant negative correlation with urbanization and total drainage area. Substrate scores are those from the QHEI surveys (Table 17) and include factors rating the extent of siltation, embeddedness and other variables. We found that higher substrate scores, which should be associated with improved stream habitat were in smaller subwatersheds and those draining areas with less urbanization. The average of the August and May QHEI scores was found to correlate with four land use types. Positive correlations were found between QHEI score and the relative proportions of the upstream drainage area that is pasture, forests, or wetland; QHEI score was negatively correlated with the relative proportion of the upstream drainage area that is row crop.

The subwatershed estimates of phosphorus and sediment loadings were not significantly correlated with any factor, including the substrate metrics in the QHEI.

Lammert and Allan (1999) found significant correlation between catchment forest or agricultural land use/cover and several instream habitat variables, including stream riparian index. Agricultural land use/cover was negatively correlated to riparian width, and positively correlated with channel width and bank width. They found the opposite true for forested area. In another study of central Michigan streams, Richards *et al.* (1996) concluded that whole watersheds may be as important as 100-m stream buffers for determining stream habitat quality, which in turn will regulate the benthic assemblage. Substrate characteristics, bank erosion, and instream woody debris were strongly related to riparian buffer quality. Riparian buffers filter particulate runoff and alter the patterns of erosion, both of which influence stream habitat and the balance and diversity of the benthic community (Ormerod *et al.* 1993)

6.2 SUBBASIN RECOMMENDATIONS

This section identifies the general types of pollution control investments we recommend for the subwatersheds in the study area. These recommendations are based on point and nonpoint source pollution source identification and estimates, environmental health information and, to some extent, land use/cover data. Exhibit 47 tabulates the management recommendations for each subwatershed.

6.2.1 Pigeon Creek - Locust Creek (Lower)

HUC 05140202040120, Pigeon Creek-Locust Creek (Lower), is subwatershed 1 on Exhibit 10. Major sources of pollutants include combined sewer overflows and runoff from urban and agricultural land. High coliform concentrations were observed during dry weather sampling of Locust Creek. Recommendations for this subwatershed include:

1. Preserve what remains of the riparian corridor along Pigeon Creek, and be vigilant for opportunities to restore the floodplain and expand recreational opportunities.
2. Prepare and implement the Long-Term Control Plan (LTCP) for the Pigeon Creek CSOs.
3. Implement urban and agricultural best management practices (BMPs) to the maximum extent possible.

6.2.2 Locust Creek Headwaters

HUC 05140202040110, Locust Creek Headwaters, is subwatershed 2 on Exhibit 10. This subwatershed drains to Pigeon Creek-Locust Creek (Lower). Major sources of pollutants include runoff from residential and agricultural land. High coliform concentrations observed there during dry weather sampling may be the source of lower Locust Creek coliform contamination. High nutrient concentrations, poor riparian conditions and erosion of highly erodible soils (Fairpoint) are significant problems for Locust Creek. Recommendations for this subwatershed include:

1. Preserve remaining riparian corridors along tributary streams, and be vigilant for opportunities to restore stream riparian areas.
2. Institutionalize sustainable development. Guidelines for sustainable community development are available from the EPA (1996), Center for Watershed Protection (1998) and Harza (in preparation).
3. Implement urban and agricultural best management practices (BMPs) to the maximum extent possible.
4. Prepare farm nutrient management plans.

6.2.3 Pigeon Creek – Kleymeyer Park

HUC 05140202040100, Pigeon Creek – Kleymeyer Park, is subwatershed 3 on Exhibit 10. This subwatershed is two-thirds urbanized. Major sources of pollutants include combined sewer overflows and runoff from urban and agricultural land. High nutrient concentrations were observed during dry weather sampling of Pigeon Creek in this area.

In spite of wet weather CSOs, we did not find *E. coli* levels during dry weather to exceed the state standard. The stream is ranked in the second quartile of biotic integrity due to favorable FBI scores. Recommendations for this subwatershed include:

1. Preserve what remains of the riparian corridor along Pigeon Creek, and be vigilant for opportunities to restore the floodplain and expand recreational opportunities.
2. Prepare and implement the LTCP for the Pigeon Creek CSOs.
3. Implement urban best management practices (BMPs) to the maximum extent possible.
4. Institutionalize sustainable development.

6.2.4 Pigeon Creek – Harper Ditch

HUC 05140202040080, Pigeon Creek – Harper Ditch, is subwatershed 4 on Exhibit 10. Major sources of pollutants include combined sewer overflows and runoff from urban and agricultural land. High nutrient and coliform bacteria concentrations were observed during dry weather sampling of Pigeon Creek in this area, particularly at PC6. Pigeon Creek in this area is ranked in the fourth quartile of biotic integrity due to poor water quality and physical habitat conditions. This subwatershed is rapidly developing. Recommendations for this subwatershed include:

1. Preserve the riparian corridor along Pigeon Creek, and continue to seek opportunities to restore the floodplain and expand recreational opportunities.
2. Prepare and implement the LTCP for the Pigeon Creek CSOs.
3. Implement urban and agricultural best management practices (BMPs) to the maximum extent possible.
4. Institutionalize sustainable development.

6.2.5 Pigeon Creek – Crawford Brandeis Ditch

HUC 05140202040010, Pigeon Creek – Crawford Brandeis Ditch, is subwatershed 5 on Exhibit 10. Major sources of pollutants include runoff from urban and agricultural land. Pigeon Creek in this area is ranked in the fourth quartile of biotic integrity due to poor water quality and physical habitat conditions. Prime farmland is being rapidly urbanized. Recommendations for this subwatershed include:

1. Preserve the riparian corridor along Pigeon Creek, and continue to seek opportunities to restore the floodplain and expand recreational opportunities.
2. Implement urban and agricultural best management practices (BMPs) to the maximum extent possible.
3. Institutionalize sustainable development.

6.2.6 Weinsheimer Ditch

HUC 05140202030060, Weinsheimer Ditch, is subwatershed 6 on Exhibit 10. Major sources of pollutants include runoff from agricultural land and point source discharges. This subwatershed is heavily developed for row crop agriculture. This stream ranked in the fourth quartile for biotic integrity during to poor habitat and water quality. Soil loss rates and instream siltation are relatively high. High nutrient and coliform concentrations were also observed. Recommendations for this subwatershed include:

1. Implement agricultural best management practices (BMPs) to reduce sheet and bank erosion.
2. Aggressively develop conservation buffers and nutrient management plans.
3. Create treatment wetlands.

6.2.7 Pigeon Creek – Barnes Ditch

HUC 05140202030070, Pigeon Creek – Barnes Ditch, is subwatershed 7. Major sources of pollutants include runoff from agricultural land and point source discharges. Stollberg Ditch is very degraded due to poor quality discharges from the Chandler municipal wastewater treatment plant. Pigeon Creek has heavy siltation and high suspended soilids concentrations in this area. Predicted soil loss rates are relatively high, especially in areas with Fairpoint soils. High nutrient and coliform concentrations were observed at all monitoring stations. A significant natural feature of this subwatershed is the remnant forested wetlands along Pigeon Creek. These floodplain wetlands may be useful in mitigating point source pollution from Chandler WWTP by altering flows and improving hydraulic retention times in wetland areas. Wetlands constitute 18% of land cover in this subwatershed. Management recommendations for this subwatershed include:

1. Implement agricultural best management practices (BMPs) to reduce sheet erosion. Target highly erodible Fairpoint soils.
2. Preserve floodplain forested wetlands and riparian forest buffers.
3. Improve operations at Chandler WWTP.
4. Enhance floodplain wetlands for water quality improvement.

6.2.8 Blue Grass Creek – Dennis Wagner Ditch

HUC 05140202040060, Blue Grass Creek – Dennis Wagner Ditch, is subwatershed 8. Row crop agriculture is 54% of this subwatershed. Streams are channelized and physical habitat is very poor. Due to high nutrient and coliform concentrations, poor habitat and high FBI score, this stream is in the fourth quartile in biotic integrity. The subwatershed drains some reclaimed mined lands. Management recommendations for this subwatershed are:

1. Implement agricultural BMPs.
2. Preserve remaining riparian corridors.
3. Preserve remaining forested wetlands.
4. Create treatment wetlands targeting agricultural runoff.
5. Prepare farm nutrient management plans.

6.2.9 Blue Grass Creek – Firlick Creek

HUC 05140202040070, Blue Grass Creek – Firlick Creek, is subwatershed 9 in Exhibit 10. Row crop agriculture is about 43% of this subwatershed. Forest covers about 20% of this subwatershed. Unfortunately, the streams are channelized and physical habitat is poor. Lower Blue Grass Creek ranks in the third quartile of biotic integrity; Firlick Creek was not inventoried. Management recommendations for this subwatershed are:

1. Implement agricultural BMPs.
2. Create riparian buffers.
3. Create treatment wetlands targeting agricultural runoff.
4. Restore stream corridor. Guidelines for stream corridor restoration are available from NRCS (1998).

6.2.10 Blue Grass Creek – Stubbs Fruedenberg Ditch

HUC 05140202040040, Blue Grass Creek – Stubbs Fruedenberg Ditch, is subwatershed 10. Row crop agriculture is about one-third of this subwatershed. This subwatershed drains active and reclaimed mined lands, including the recently created 2,500-acre Blue Grass Fish and Wildlife Area. Unfortunately, many of the streams are channelized and physical habitat is poor. Stream habitat improvements in this area could include restoration of meanders and riparian habitat. Due to poor habitat, as well as high nutrient and coliform concentrations, Blue Grass Creek ranks in the fourth quartile of biotic integrity. Management recommendations for this subwatershed are:

1. Implement agricultural BMPs.
2. Restore Blue Grass Creek and Stubbs Fruedenberg Ditch in partnership with the Indiana DNR and the Blue Grass Fish and Wildlife Area.
3. Create riparian buffers.

6.2.11 Schlensker Ditch

HUC 05140202040050, Schlensker Ditch, is subwatershed 11 in Exhibit 10. Row crop agriculture is about 40% of this subwatershed. The streams have been channelized and physical habitat is poor. No biological or water quality data were collected in this subwatershed. Management recommendations for this subwatershed are:

1. Implement agricultural BMPs, targeting Zanesville soils.
2. Create riparian buffers.
3. Restore stream corridor.

6.2.12 Little Pigeon Creek

HUC 05140202040090, Little Pigeon Creek, is subwatershed 12 on Exhibit 10. This subwatershed includes the area along US41 north of Evansville, where prime farmland is being rapidly developed. Major sources of pollutants include runoff from commercial, residential and agricultural land. The Evansville Airport is located in this subwatershed; we were unable to review their stormwater pollution prevention plan. Darmstadt WWTP is located in this subwatershed. High BOD and coliform bacteria, and low DO concentrations were observed during dry weather sampling of Little Pigeon Creek and we are unsure of their source. Recommendations for this subwatershed include:

1. Implement airport BMPs.
2. Implement urban and agricultural BMPs
3. Institutionalize sustainable development.
4. Conduct additional diagnostic testing to identify the source of coliforms and BOD.

6.2.13 Unnamed Tributary (Blue Grass Creek)

HUC 05140202040030 is drained by an unnamed tributary to Blue Grass Creek. It is subwatershed 13 on Exhibit 10. We have no water quality or biological information on this subwatershed. The subwatershed is 48% row crop agriculture, which is responsible for the majority of aquatic pollution. Management recommendations include:

1. Implement agricultural BMPs.
2. Restore stream corridors.

6.2.14 Blue Grass Creek Headwaters

HUC 05140202040020, Blue Grass Creek headwaters, is subwatershed 14 on Exhibit 10. We have no water quality or biological information on this subwatershed. The subwatershed is 50% row crop agriculture. This land use, together with the Elberfeld WWTP, constitutes the major sources of aquatic pollution. While the wastewater treatment plant has a poor compliance record, it is currently being upgraded. Bioassessment of downstream reaches of Bluegrass Creek did not indicate significant impairment. Management recommendations include:

1. Implement agricultural BMPs.
2. Restore stream corridors.
3. Improve the performance of the Elberfeld WWTP

6.2.15 Pigeon Creek – Clear Branch

HUC 05140202030040, Pigeon Creek – Clear Branch, is subwatershed 15. The subwatershed is 25% row crop agriculture. This subwatershed contains some active and reclaimed mined lands. We observed high nutrient concentrations in Pigeon Creek. While the physical habitat of Pigeon Creek has been severely impaired by the construction of the Wabash and Erie Canal, significant bottomland wetlands remain. In fact, wetlands constitute 25% of this subwatershed. Management recommendations include:

1. Implement agricultural BMPs.
2. Study the extensive bottomland wetlands for enhanced legal protection.
3. Study the restoration of Pigeon Creek to its original channel, enhancement of the stream corridor and improved use of floodplain wetlands for flood detention and water quality benefits.

6.2.16 Squaw Creek

HUC 05140202030050, Squaw Creek, is subwatershed 16 in our study. Row crop agriculture is about 17% of this subwatershed; nearly half is pasture. There is a high rate of soil loss in this subwatershed, particularly on highly erodible Fairpoint soils. Notable water quality features include high conductivity and relatively high nutrient levels. This stream ranks in the second quartile of biotic integrity. Management recommendations for this subwatershed are:

1. Preserve and expand Squaw Creek riparian corridors.
2. Implement agricultural BMPs, targeting Fairpoint soils.
3. Preserve bottomland forests and wetlands.
4. Prepare farm nutrient management plans.

6.2.17 Big Creek – Little Creek/Plum Branch

HUC 05140202030020, Big Creek – Little Creek/Plum Branch, is subwatershed 17. Row crop agriculture is about 19% of this subwatershed while wetlands occupy about 12%. There is a relatively high rate of soil loss in this subwatershed, particularly on highly erodible Fairpoint soils. This watershed drains active and reclaimed mined lands. Notable water quality surveys found high conductivity, possibly reflecting the mining that has occurred there. Nevertheless, this stream ranks in the top quartile of biotic integrity. Management recommendations include:

1. Implement agricultural BMPs, targeting Fairpoint soils.
2. Implement mining BMPs.
3. Preserve remaining bottomland forests and wetlands.

6.2.18 Big Creek – Headwaters

The headwater of Big Creek is subwatershed 18, HUC 05140202030010. Forests and pasture are the dominant land cover types there. We did not sample this subwatershed and consequently have no biological or water quality data to characterize it. There is a high rate of soil loss in this subwatershed, particularly on highly erodible Fairpoint soils. This watershed drains active and reclaimed mined lands. There is at least one industrial point source discharge (from a mine) and Lynnville WWTP discharging to this subwatershed. Management recommendations include:

1. Implement agricultural BMPs, targeting Fairpoint soils.
2. Implement mining BMPs.
3. Preserve remaining bottomland forests and wetlands.

6.2.19 Big Creek – Wye In RR (Pigeon Creek)

HUC 05140202030030, Big Creek – Wye In RR, is subwatershed 19. Row crop agriculture is 52% of this subwatershed while wetlands occupy about 19%. Big Creek has been severely channelized in this area, but bioassessment data rank it in the first quartile of stream biotic integrity. There are extensive forested wetlands associated with the Pigeon Creek floodplain. Management recommendations include:

1. Implement agricultural BMPs.
2. Preserve remaining bottomland forests and wetlands.
3. Protect and expand riparian corridors.
4. Incorporate lower Big Creek into the restoration of Pigeon Creek channel and improved use of floodplain wetlands for water quality benefits.

6.2.20 Smith Fork – Headwaters

The headwater area of Smith Fork is subwatershed 20, HUC 05140202020060. Row crop agriculture constitutes 48% of land cover here; deciduous forest and pasture are also dominant land cover types. There is a relatively high rate of soil loss in this subwatershed, particularly on highly erodible Fairpoint soils. This watershed drains active and reclaimed mined lands. There is at least one industrial point source discharge (from a mine). Despite extensive channelization of Smith Fork for improved agricultural drainage, Smith Fork is in the first quartile of stream biotic integrity. Management recommendations for this subwatershed include:

1. Implement agricultural BMPs, targeting Fairpoint soils.
2. Implement mining BMPs.
3. Preserve remaining forests.
4. Create treatment wetlands.
5. Restore stream corridor values and functions. Guidance is available from the NRCS (1998).

6.2.21 Smith Fork – Halfmoon Creek

HUC 05140202020070, Smith Fork – Halfmoon Creek, is subwatershed 21 in this study (Exhibit 10). Row crop agriculture constitutes 66% of land cover here. There are remnant wetland forests along the Pigeon Creek floodplain constituting about 12% of the subwatershed. There are small-scale oil wells in this area. As with the headwaters, lower Smith Fork and Halfmoon Creek has been extensively channelized for improved agricultural drainage. FBI scores at SF1 suggest that water quality is fair to good. In the mid-1990s, a Section 104(b)(3) grant funded grassed waterways and filter strips in the Halfmoon Creek tributary subwatershed. Management recommendations for this subwatershed include:

1. Expand agricultural BMPs.
2. Implement oil well BMPs.
3. Preserve remaining forests and wetlands.
4. Restore stream corridor values and functions.

6.2.22 Pigeon Creek – Snake Run

HUC 05140202020050, Smith Fork – Halfmoon Creek, is subwatershed 22. Row crop agriculture constitutes 76% of land cover here, with the balance being pasture and deciduous forest. There are remnant wetland forests along the Pigeon Creek floodplain constituting about 12% of the subwatershed. This subwatershed was not part of the bioassessment surveys so we have no water quality or biological information. The streams have been extensively channelized for agricultural drainage. A floodway construction permit was issued by the DNR in February 2000 for additional channel reshaping to improve drainage and flood control. Management recommendations for this subwatershed include:

1. Implement agricultural BMPs.
2. Preserve remaining forests and wetlands.
3. Restore stream corridor values and functions.
4. Monitor recently channelized portion of Pigeon Creek, between the county line and the confluence with West Fork, for compliance with the special conditions in the floodway permit (FW-20,093).

6.2.23 Hurricane Creek Ditch

HUC 05140202020030, Hurricane Creek Ditch, is subwatershed 23. Row crop agriculture constitutes 74% of land cover here. There is a relatively high rate of soil loss in subwatershed 23, and the Alford series soils contribute the largest erosion rates. The Haubstadt WWTP is in this subwatershed. This facility has historically performed poorly. It is currently being upgraded and effluent quality should improve. We observed high nutrient and coliform bacteria concentrations in the stream, which together with supersaturated DO and high pH, imply organic enrichment. The streams have been extensively channelized for agricultural drainage. Management recommendations for this subwatershed include:

1. Complete upgrading of the Haubstadt WWTP and provide increased opportunities for training of operators.
2. Implement agricultural BMPs.
3. Preserve remaining forests and wetlands.
4. Restore stream corridor values and functions.

5. Prepare farm nutrient management plans.

6.2.24 West Fork Creek

HUC 05140202020040, West Fork Creek or Toops Ditch, is subwatershed 24. Row crop agriculture constitutes 88% of land cover in this area, with the balance principally being pasture and urban lands around Fort Branch. Very few wetlands (<1% of the area) remain in this subwatershed. There are two permitted point source discharges: Fort Branch WWTP and a meat processing facility, the former of which has a history of poor performance during wet weather. The lower end of West Fork receives pollutant loadings from Hurricane Creek (HUC 05140202020030). This subwatershed has a relatively high soil loss rate. Some steeper slopes (Alford series) may warrant special study and recommendations. The streams have been extensively channelized for agricultural drainage and there is a near-total lack of riparian buffers. The stream has high nutrient and coliform bacteria concentrations, but still ranks highly for biotic integrity among Pigeon Creek watershed streams. Management recommendations for this subwatershed include:

1. Implement agricultural BMPs, targeting Alford soils.
2. Study wet weather discharges at the Fort Branch WWTP.
3. Identify source(s) of dry weather coliform bacteria loads.
4. Restore stream corridor values and functions.
5. Prepare farm nutrient management plans.

6.2.25 Pigeon Creek – Clear Fork Ditch

HUC 05140202020020, Pigeon Creek – Clear Fork Ditch, is subwatershed 25. Row crop agriculture constitutes 80% of land cover in this area, with the balance principally being pasture. Very few wetlands (<2% of the area) remain. Some areas in this subwatershed have a very high rate of soil loss (Alford series). These highly erodible lands warrant special consideration and recommendations. The streams have been extensively channelized for agricultural drainage and there are few riparian buffers. Nutrient concentrations are high. Despite these shortcomings, the stream ranks highly for biotic integrity among Pigeon Creek watershed streams. Management recommendations for this subwatershed include:

1. Implement agricultural BMPs, targeting Alford soils.
2. Restore stream corridor values and functions.
3. Prepare farm nutrient management plans.

6.2.26 Sand Creek – Muddy Fork Ditch

HUC 05140202020010, Sand Creek – Muddy Fork Ditch, is subwatershed 26. Row crop agriculture constitutes 79% of land cover in this area. Very few wetlands (<1% of the area) remain in this subwatershed. This subwatershed has a relatively high soil loss rate, due to tillage of some steeper slopes (Alford series). These areas may warrant special consideration and recommendations. The streams have been extensively channelized for agricultural drainage and there is a near-total lack of riparian buffers. The stream ranks in the top quartile for biotic integrity among Pigeon Creek watershed streams. Management recommendations for this subwatershed include:

1. Implement agricultural BMPs, targeting Alford soils.
2. Restore stream corridor values and functions.
3. Prepare farm nutrient management plans.

6.3 AGRICULTURAL BEST MANAGEMENT PRACTICES

Best management practices, or BMPs, are restrictions, structures or practices that mitigate the adverse anthropogenic effects on runoff quality and/or quantity. The study area watershed is largely agricultural. There is a broad range of BMPs for agricultural lands. Appendix D discusses many of these. For the lands in the study area where corn and soybean production is the dominant use, some of the most effective BMPs include conservation tillage, conservation buffers and nutrient management.

6.3.1 Conservation Tillage

Conservation tillage, or crop residue management, involves leaving at least 30% of the ground covered with plant residue after planting. Varieties of conservation tillage include no-till/strip-till, ridge-till and mulch-till. Conservation tillage is widely practiced throughout Indiana and the Midwest. Conservation tillage improves water quality by reducing soil erosion and transport. It also improves soil quality by increase organic content, moisture and nutrient retention capacity, and tilth.

Tables 24 through 26 contain the most recent data available on tillage practices for the study area. These data were exported from the Transect Program administered by Purdue University. Data on previous years are incomplete and we are not able to ascertain a trend in adoption of conservation tillage practices. Watershed wide, conservation tillage systems were used on 25% of cropland in 1997, 16% of cropland in 1998, and 33% of cropland in 2000. Data on the conservation tillage in the watersheds are insufficient to demonstrate trends. In the year 2000, HUC 05140202030, which is principally Warrick County, had a high of 51% of cropland in conservation tillage.

The previous year's crop essentially controls the amount of tillage that can be performed while retaining 30% residue cover in the field. This may require crop rotation, as corn produces significant residue that can be left on the field, but soybeans do not.

All Indiana counties have extension agents available to provide technical assistance for implementing conservation tillage programs. In a 1997 nationwide survey of growers, the Natural Resource Conservation Service (NRCS) found that operation costs were rarely an impediment to implementing conservation tillage practices (cited in NRCS 1999). More common reasons stated in that survey were the expense of equipment changes and weed problems. As illustrated in Table 42, operating costs may be less under no-till systems than conventional tillage system. Costs for procuring the equipment however can be challenging for some operators.

Table 42

OPERATING COSTS ($/acre) FOR CONVENTIONAL TILLAGE VERSUS NO-TILL (adapted from NRCS 1999)

Crops	Conventional Tillage	No-till System	Increase/decrease
Corn			
Operating/machinery	17	5	–12
Material	100	95	–5
Other	5	5	0
Total	122	105	-17
Soybeans			
Operating/machinery	14	6	–8
Material	55	83	28
Other	3	4	1
Total	72	93	21
Wheat			
Operating/machinery	12	6	–6
Material	38	49	11
Other	3	3	0
Total	53	58	5

6.3.2 Conservation Buffers

Since settlement by Europeans, the watershed landscape has been dramatically altered. Over the years, settler activities have changed the dynamic equilibrium of the creek and its upslope systems. The cumulative effect of these changes has been degradation of water quality, loss of floodplain storage, diminished wildlife populations, and decreased aesthetic and recreational values. We have recommended stream corridor restoration efforts in nearly all subwatersheds in the Pigeon Creek watershed. This restoration is a complex endeavor that begins with the recognition that human-induced changes that begun nearly two centuries ago have damaged the structure and function of the ecosystem and prevent the recovery of the watershed to a sustainable condition. These human-induced changes include:

- Creation of the Wabash and Erie Canal
- Channelization of first and second order streams to facilitate agricultural drainage
- Draining of wetlands
- Dredging, clearing and snagging of Pigeon Creek to reduce flooding
- Increased watershed imperviousness
- Mineral extraction and massive landscape alteration
- Loss and/or alteration of vegetative cover across the watershed
- Addition of nutrients and other pollutants to the streams

Among the net results of these alterations are:

- A watershed that is 100% impaired for aquatic life support due to poor physical habitat
- Poor water quality throughout the watershed
- High rates of soil loss
- Near extirpation of nine species of mussels

NRCS (1998) presents guidelines on restoration of stream riparian processes. The massive investment over the last 200+ years in separating the stream from its watershed will require a similar level of investment to reverse, but we believe that will prove economically attractive to do so. The economic benefits of environmental restoration can prove attractive, if the investments are well founded and prudent.

Conservation buffer strips of vegetation can, if properly planned and maintained, greatly reduce the runoff of soil and associated pollutants to nearby receiving waters. There are many practices that can be broadly grouped together as conservation buffers:

- Riparian buffers along streams
- Contour grass strips
- Field border buffers
- Filter strips

- Grassed swales and waterways
- Hedges or living snow fences
- Wetlands
- Other strategically planted vegetation that can intercept pollution or reduce wind or water erosion

Besides reducing sediment, nutrients and pesticides in runoff water, conservation buffers can greatly increase wildlife habitat. Filter strips should not be less than 20 feet, and protection of some resources may require much wider vegetation strips. Upgradient land slopes greater than 6% should have wider strips, possibly as wide as 130 feet. Floodplain riparian buffers having higher flows and longer duration flooding may need to be upwards of 200-feet wide.

The USDA's Conservation Reserve Program (CRP) is an excellent opportunity for establishing conservation buffers. Costs for installation of conservation buffers ranges widely, as expected given the broad variety of buffer types. The CRP shares in the cost of installation of conservation buffers and provides for long term contracts for the setting aside of eligible lands.

Appendix E is a model ordinance for stream buffers. Enacting such as ordinance is a significant step towards sustainable watershed management.

6.3.3 Nutrient Management

A crop nutrient management plan can increase the efficiency of crop fertilizer use while reducing nutrient losses to streams and lakes. Nutrient management reduces both production risk and environmental risk, and can increase agricultural profitability. Classically, nutrient management plans contain the following ten components:

1. Field Map. Acreage, soils, water bodies and other sensitive habitats.
2. Soil Test. Determining soil nutrient status.
3. Crop Rotation. Sequencing of crops affects fertilizer needs.
4. Estimated Crop Yield.
5. Sources and Forms of Nutrients. Manure/sludge fertility analysis and understanding of inorganic fertilizers.
6. Sensitive Environmental/Social Areas.

7. Recommended Rates of N, P & K.
8. Timing of Applications.
9. Methods of Applications.
10. Annual Review and Update.

Again, all Indiana counties have extension agents available to provide technical assistance for developing nutrient management plans. Recent NRCS guides have estimated consulting for preparation of nutrient management plans at $5/acre (NRCS 1999). Based upon this unit rate and adjusting for inflation, plan development for the entire study area will cost approximately $970,000 (Table 43). While nutrient management plans are appropriate for most, if not all, farms, in Section 6.2, we recommended nutrient management plans specifically for subwatersheds 2, 6, 8, 16, 23, 24, 25 and 26. The cost of preparation of nutrient management plans in these eight subwatersheds is approximately $410,000. Priority for nutrient management resources should be given to farms nearest perennial streams in this subwatersheds.

6.4 URBAN BEST MANAGEMENT PRACTICES

Urban best management practices (BMPs) are actions or methods that could be used to reduce flow rates and contaminant concentrations in urban runoff. There are essentially two types of urban BMPs: source controls and treatment controls. Source controls are practices that prevent pollution by reducing the amount of pollutants at their source from entering the runoff. Treatment controls refer to devices that remove pollutants from the runoff.

6.4.1 Source Controls

Source controls are pollution prevention programs that target contaminants at their source. Since BMP technology is still imperfect, a good urban BMP program will require certain source controls be implemented in addition to the existing development. Some of the more appropriate and effective source control BMPs are described below.

Table 43

ESTIMATED COSTS FOR DEVELOPMENT OF NUTRIENT MANAGEMENT PLANS

Subwatershed	Agricultural Land (acres)	Costs
1. Pigeon Creek - Locust Creek Lower	2,529	$ 13,939
2. Locust Cr Headwater	2,971	$ 16,378
3. Pigeon Creek - Kleymeyer Park	416	$ 2,295
4. Pigeon Creek - Harper Ditch	2,361	$ 13,017
5. Pigeon Cr - Crawford Brandeis Ditch	4,357	$ 24,016
6. Weinsheimer Ditch	7,147	$ 39,397
7. Pigeon Creek - Barnes Ditch	8,781	$ 48,407
8. Blue Grass Cr - Dennis Wagner Ditch	3,591	$ 19,797
9. Blue Grass Cr - Firlick Ditch	2,985	$ 16,452
10. Blue Grass Cr - Stubbs Fruedenberg	2,004	$ 11,045
11. Schlensker Ditch	3,194	$ 17,606
12. Little Pigeon Creek	4,496	$ 24,783
13. Unnamed Trib to Blue Grass Cr	3,791	$ 20,900
14. Blue Grass Creek Headwaters	4,560	$ 25,135
15. Pigeon Creek - Clear Branch	6,763	$ 37,280
16. Squaw Creek	5,459	$ 30,095
17. Big Creek - Little Creek	6,099	$ 33,623
18. Big Creek Headwaters	3,797	$ 20,930
19. Big Creek – Wye	5,046	$ 27,818
20. Smith Fork Headwaters	10,739	$ 59,196
21. Smith Fork - Halfmoon Creek	8,416	$ 46,394
22. Pigeon Creek - Snake Run	12,557	$ 69,220
23. Hurricane Ditch Creek	9,231	$ 50,887
24. West Fork Creek	18,118	$ 99,877
25. Pigeon Creek - Clear Fork Ditch	10,250	$ 56,504
26. Sand Creek - Muddy Fork Ditch	10,125	$ 55,812
Subtotal	159,783	$ 880,804
	Contingency @ 10%	$ 88,080
	Total	$ 968,884

Public education is a practice intended to educate the general public the proper way of using, storing, and disposal of a variety of hazardous household products that will enter stormwater. The public must become aware that many of the constituents are used in the home and that the way these products are used and disposed of can affect the stormwater quality. Public education about watershed management is discussed in more detail in Appendix A.

The promotion of good housekeeping practices by municipal employees, the general public, and small businesses can be another effective source control BMP. Good housekeeping practices include storing hazardous products securely, safely, and in original containers; reading and following product instructions; and properly disposing of products. Staffs are needed to train municipal employees and coordinate public education efforts.

Conducting street sweeping on a regular basis can reduce the runoff of pollutants with storm water from street surfaces. When done regularly, street sweeping can remove 50 to 90% of street pollutants from polluting stormwater. Street cleaning program requires a significant capital and O&M budget. A sweeper can cost from $65,000 to $120,000 per machine, depending on the type. Evansville has a street sweeping program, as mentioned in Chapter 5.

Catch basins must be cleaned periodically to maintain their ability to trap sediment and thereby prevent sewer blockages. Catch basin cleaning can improves both the aesthetics and the quality of the receiving water body. A catch basin that becomes a source rather than a sink for sediments is not being cleaned frequently enough. A catch basin cleaning program also requires a significant capital and O&M budget. For budgetary purposes, Southeastern Wisconsin Regional Planning Commission (1991) recommended a $8 cleaning cost per basin in communities equipped with vacuum street sweepers. Manual basin cleaning typically costs approximately $16 per basin. Institutional changes are recommended for improvements to Evansville's catch basin cleaning program (Chapter 5).

Since vegetation can help to prevent erosion, take up nutrients, reduce the volume and rate of runoff, and increase groundwater recharge, control can help to maintain the vegetative ground cover on land. Vegetation control typically involves a combination of mechanical methods and careful application of herbicides.

6.4.2 Treatment Controls

Unlike source controls, treatment controls remove pollutants from the runoff. Treatment controls are most applicable in developing and redeveloping areas. To enhance the performance and longevity of treatment control BMPs, source controls should also be part of the treatment train. Without implementing source controls, the investment in the treatment control facilities will be lost. Some of the more appropriate and effective treatment control BMPs are described below.

Biofilters are vegetation filter strips designed to remove suspended solids by filtering through the vegetation and settling. Dissolved constituents may also be removed through chemical or biological mechanisms mediated by the vegetation and the soil. Some infiltration also occurs through the underlying soil cover.

Detention/retention ponds are the most effective management practices at removing pollutants through settling. Soluble nutrients and organic matter are removed through plant uptake and bacterial activity in the permanent pool of water. They also provide full control of peak discharges for large design storms.

The use of constructed wetlands to treat urban and agricultural storm water is popular. With functions similar to those of retention/detention ponds, constructed wetlands remove pollutants by impounding runoff and settle and retain suspended solids and associated pollutants. They can also be beneficial in the preservation and restoration of the natural balance between surface and ground water, and wildlife habitats. In urban surroundings, the availability of land is frequently a constraint on the applicability of this BMP. Constructed wetlands are discussed in greater detail below.

Hydrodynamic separators are structures built to remove sediments and other pollutants. Having a settling unit in the structure, sediments are efficiently separated by the flowing water. These separators are most effective in removing heavy particulates and floatables. The capital cost of these structures can range from $2,300 to $40,000 per pre-cast unit.

Street storage can be used to reduce the rate of runoff entering the sewer system. Street cross sections and storm drain inlets have to be modified so that the street surfaces can store and convey runoff during peak storm events and reduce the hydraulic loading to the combined sewer. Chapter 5 also addresses this BMP.

6.5 CONSTRUCTED WETLANDS

Source controls alone may not be sufficient to bring pollution loadings to levels where aquatic life is not stressed. Over the last two decades, interest has increased for the use of constructed wetlands for treatment of nonpoint source pollution. Constructed wetlands are designed specifically for water treatment and serve in a similar capacity as other water quality BMPs, to minimize pollution prior to its entry into streams, lakes and other receiving waters.

Among the most important treatment processes in wetlands are the purely physical processes of sedimentation. Sedimentation accounts for the relatively high removal rates for suspended solids, the particulate fraction of organic matter and sediment-bound nutrients and metals. Pathogens show good removal rates in constructed wetlands via sedimentation, natural die-off, and UV degradation. Dissolved constituents such as soluble organic matter, ammonia and ortho-phosphorus tend to have lower removal rates. Soluble organic matter is largely degraded aerobically by bacteria and periphyton. Ammonia is removed through microbial nitrification-denitrification, plant uptake, and volatilization. Nitrate is removed through denitrification and plant uptake. Phosphorus is removed mainly through soil sorption, plant assimilation and burial. Phosphorus removal rates are variable and, while phosphorus removal may be very high in newly constructed wetlands, phosphorus removal rates typically are lower than those of nitrogen in older, established wetlands.

General ranges of removal for various pollutants by constructed wetlands are given below.

TABLE 44

CONSTRUCTED WETLAND POLLUTANT REMOVAL EFFICIENCY
(Source: Schueler, 1987, Schueler *et al.* 1992)

Pollutant	Efficiency
Bacteria	High
Oil and Grease	Very high
BOD	Moderate
Trace metals (sediment-bound)	High
Sediment	High
Total Phosphorus	High
Total Nitrogen	Moderate

Development of constructed wetlands for treatment remains an emerging technology and design criteria continue to evolve. General design considerations include the requirement to reduce runoff velocities and provide opportunities for sedimentation. Generally designers attempt to maximize the hydraulic residence time and the distribution of flow over the treatment area.

Constructed wetlands can be a very effective part of a BMP system. While constructed wetlands can be nearly universally applied to point and nonpoint sources in the study area, we have recommended constructed wetlands be considered for priority development in four subwatersheds: 6, 7, 8 and 9. Costs for development of wetlands can vary with size, site topography and other factors. Wetlands are generally sized according to treatment needs for the volume and quality of inflows. Treatment wetland unit costs can range from $5,000 per acre to upwards of $25,000 per acre. Wetland construction requires permits from the US Army Corps of Engineers, the IDNR, Indiana Department of Environmental Management (IDEM) and, if the site in on a regulated drain, the approval of the County Drainage Board.

We recommend that the appropriate SWCD (or other local sponsor) actively seek the involvement of local landowners in these four subwatersheds. We recommend their involvement initially be as advisors to a LARE-sponsored engineering feasibility study for constructed wetlands in Weinsheimer Ditch, Barnes Ditch, Dennis Wagner Ditch and Firlick Creek subwatersheds. As landowner interest and understanding of wetland systems and their benefits increases, one or more could possibly serve as co-sponsor for construction of the wetland.

A novel wetland development technique currently being pioneered by Harza and some non-profit partners in Illinois involves construction of a cable dam (Exhibit 48). This technique mimics the processes facilitated by beaver dams, that now are rare in legal drains and areas without beaver.

6.6 FUNDING SOURCES

There are several agencies providing funding for projects which address water quality, erosion control, storm water, nonpoint source pollution, wetlands, and wildlife. Funding agencies include the branches of the United States Department of Agriculture (Natural Resources Conservation Service (NRCS) and the United States Forest Service), branches of the United States Department of Interior (Fish and Wildlife Service and the Bureau of Reclamation), United States Environmental Protection Agency, and the United States Army Corps of Engineers.

Many of these funding agencies provide money to the states, which in turn, fund such programs as IDEM's Section 319 Nonpoint Source (NPS) Program. Other programs are financed at the state level, such as the LARE Program. At the county level, Indiana's Drainage Code provides authority to Drainage Boards to finance certain types of watershed management projects. We believe that this is an underutilized source of financing of watershed management projects.

For privately owned land, the USDA offers landowners natural resource programs that provide incentives and assistance to landowners for implementing conservation practices on the land. Some of the USDA's natural resource programs include :

- Conservation Reserve Program (CRP)
- Conservation Reserve Enhancement Program (CREP)
- Environmental Quality Incentives Program (EQIP)
- Forest Legacy Program (FLP)
- Forest Stewardship Program (FSP)

- Forestry Incentives Program (FIP)
- Small Watershed Program
- Stewardship Incentive Program
- Wetlands Reserve Program
- Wildlife Habitat Incentives Program

6.6.1 Conservation Reserve Program (CRP)

The CRP encourages farmers to plant permanent covers of grass and trees on land subject to erosion. Farmers are compensated for helping to reduce soil erosion and improve water quality.

6.6.2 Conservation Reserve Enhancement Program (CREP)

The CREP uses financial incentives to encourage farmers and ranchers to enroll in the Conservation Reserve Program in contracts of 10 to 15 years in duration to remove land from agricultural production.

6.6.3 Environmental Quality Incentives Program (EQIP)

The EQIP assists landowners in conserving and improving natural resources. Only areas with significant natural resource concerns are selected to join the EQIP. Activities must be carried out according to a conservation plan.

6.6.4 Forest Legacy Program (FLP)

The purpose of the FLP is to conserve the resource values of forest land. Conservation easements or purchases are used to protect land from being converted to non-forest uses.

6.6.5 Forest Stewardship Program (FSP)

The FSP helps non-industrial forest land landowners to prepare natural resource management plans to keep the forests productive and healthy.

6.6.6 Forestry Incentives Program (FIP)

The FIP is designed to support good forest management practices on non-industrial forestlands while meeting future demands for wood products.

6.6.7 Small Watershed Program

The Small Watershed Program helps participants solve natural resource and related economic problems through technical and financial assistance.

6.6.8 Stewardship Incentive Program

The Stewardship Incentive Program offers technical and financial assistance to encourage non-industrial forestland owners keeping their lands and natural resources productive and healthy.

6.6.9 Wetlands Reserve Program

The Wetlands Reserve Program helps landowners to restore wetland by establishing conservation easements. Easements set limits on how the lands may be used in the future.

6.6.10 Wildlife Habitat Incentives Program

The Wildlife Habitat Incentives Program offers cost-share assistance in the development of habitat for fish and wildlife on private lands.

These USDA programs include both grants and loans. In general, most of the programs require cost share requirements specifying non-federal contributions from five to 75%.

6.6.11 State Revolving Loan Fund

Any pollution abatement project may be eligible for funding by the State Revolving Loan Fund (SRF). Eligible wastewater projects include:

- Wastewater treatment plant improvements
- Sewer line extensions
- Upgrades
- CSO corrections
- Infiltration/inflow projects

There is currently policy and programmatic revisions underway at IDEM that will make nonpoint source control project eligible for financing by the State Revolving Loan Fund. This is an important new facet of the SRF and presents a significant financial resource for watershed managers in the state.

The SRF was created by the Clean Water Act Amendments in 1987 and has most commonly been used to finance municipal wastewater collection and treatment projects. Indiana's SRF Program offers low-interest loans to qualified communities for the planning, design, and construction of publicly-owned wastewater facilities. The SRF currently provides the lowest cost financing for these wastewater projects. The program is jointly managed by the IDEM and the State Budget Agency (SBA). IDEM is SRF Program administrator and the SBA is financial manager. Currently, IDEM is revising its policy and nonpoint source projects will be eligible for SRF financing soon. Together, the EPA and the State of Indiana have provided over $342 million to the SRF through 1998. Although future funding is uncertain, the program will be self-sustaining through the repayment of the loans. Communities eligible to apply for SRF loans are political subdivisions including incorporated cities and towns, counties, townships, municipal corporations, conservancy districts, sanitary districts, and regional water, sewer and waste districts.

The 1995 session of the General Assembly passed Senate Bill 66 to provide a three-tiered interest rate policy for the SRF program. The new policy allows the SRF program to be more affordable to communities, especially Indiana's poorer communities. The interest rate available to a community is based on the median household income (MHI) of the service area. In addition, a community may be eligible for 0% interest for up to two years depending upon the communities' MHI.

Currently being discussed in the Indian Legislature is HB 1824. This bill, if passed, would enable a private entity to participate in the SRF program in connection with a nonpoint source pollution reduction project.

7.0 CONCLUSIONS AND RECOMMENDATIONS

This diagnostic study has examined the physical, biological and chemical effects of nonpoint source pollution on tributary streams in the Pigeon Creek watershed. Long-term water quality data for the study area is not sufficient to statistically ascertain the effectiveness of agricultural BMP adoption or urban point source reduction projects implemented to date.

We monitored instream habitat, macroinvertebrate community health, and water quality in the Pigeon Creek watershed. Predictive models of nonpoint source loadings were also developed. We used these data to rank these streams according to the level of ecological stress each was being subjected to. Five indicators were selected to rank the monitoring sites on the basis of relative biotic integrity. These indicators were: concentrations of *E. coli* bacteria, phosphorus and suspended solids, Family Biotic Index (FBI) and Qualitative Habitat Evaluation Index (QHEI). We then sorted the subwatersheds into four groups reflecting their relative biotic integrity. All these diverse indicators were used to prepare recommendations for each of 26 subwatersheds.

7.1 PROTECTION OF SELECTED AREAS

While all 26 subwatersheds are impaired for aquatic life support to some degree, among the more healthy subwatersheds, and those most warranting protection against degradation, and include principally Smith Fork (subwatersheds 20 and 21), West Fork Pigeon Creek (subwatershed 24) and Big Creek (subwatersheds 17, 18 and 19).

There are also extensive bottomland wetlands along Pigeon Creek (subwatersheds 15, 19, 21) that remain. We recommend these be studied for enhanced legal protection, perhaps in association with an overall corridor initiative for the watershed.

7.2 RESTORATION OF STREAM CORRIDOR

According to the IDEM's surface water assessment methodology, all streams in the watershed are impaired for support of aquatic life due to physical habitat degradation. No site met the IDEM's QHEI score to be considered fully supportive of aquatic life and therefore should be considered a candidate for 303(d) listing and TMDL development.

This is the effect of nearly two centuries of single-purpose water resource management for improved agricultural drainage and construction of the Wabash and Erie Canal.

To address historic stream degradation and soil erosion, we recommend extensive new investments in corridor restoration and continued investment in agricultural BMPs. Stream corridor restoration is required to improve connectivity and width of the riparian corridor; such an investment will benefit nutrient and water flow, sediment trapping during floods, water storage, wildlife migration, floral dispersal, biodiversity, and sustainability (NRCS 1998).

We have recommended stream corridor restoration efforts in nearly all subwatersheds in the Pigeon Creek watershed. This restoration is a complex endeavor that begins with the recognition that human-induced changes have damaged the structure and function of the ecosystem and prevent the recovery of the watershed to a sustainable condition. These human-induced changes include:

- Creation of the Wabash and Erie Canal
- Channelization of first and second order streams to facilitate agricultural drainage
- Draining of wetlands
- Dredging, clearing and snagging of Pigeon Creek to reduce flooding
- Increased watershed imperviousness
- Mineral extraction and massive landscape alteration
- Loss and/or alteration of vegetative cover across the watershed
- Addition of nutrients and other pollutants to the streams

To galvanize stream corridor restoration, and to provide a framework for this massive endeavor, we recommend preparation of a Master Plan and feasibility study for the restoration of Pigeon Creek to its original channel, enhancement of the stream corridor and improved use of floodplain wetlands for water quality benefits. NRCS (1998) presents guidelines on restoration of stream riparian processes.

Appendix E is a model ordinance for stream buffers. Enacting such an ordinance is a significant step towards sustainable watershed management. A reinvigorated Pigeon Creek Steering Committee, or similar stakeholder galvanizing group, will be required to drive the social, political and financial requirements of a whole-scale corridor restoration program. EWSU and EMC are currently forming a CSO Stakeholder Advisory Committee that may also present opportunities for public education and involvement.

Part of stream corridor restoration that should be supported immediately is conservation buffers in agricultural and urban areas. Besides reducing sediment, nutrients and pesticides in runoff water, conservation buffers can greatly increase wildlife habitat.

The USDA's Conservation Reserve Program (CRP) is an excellent opportunity for establishing conservation buffers in agricultural areas. Costs for installation of conservation buffers ranges widely, as expected given the broad variety of buffer types. The CRP shares in the cost of installation of conservation buffers and provides for long-term contracts for the setting aside of eligible lands.

7.3 HIGHLY ERODIBLE LANDS

According to our land use map, soils map, and sediment loss models, subwatersheds 6, 18, 20, 22, 23, 24, 25 and 26 are the priority areas for investing in soil erosion controls. These subwatersheds contain Fairpoint and Alford soils that appear to be tilled. Undoudtedly, some of these areas have since been set aside under the Conservation Reserve Program, but we do not have a theme in the GIS to compensate the model for such practices. In any case, tillage of the Fairpoint or Alford soil associations will result in very high soil loss rates and special efforts to mitigate these areas will reap significant benefits.

Conservation tillage in 2000 was practiced on approximately one-third of all cropland, being highest (51% of cropland) in Warrick County. In 2000 in Gibson County, farmers practiced conservation tillage on about 25% of croplands. There are large areas of highly erodbile Alford soils in Gibson County (Exhibit 4) that warrant conservation tillage (or CRP set aside).

7.4 POINT SOURCE CONTROLS

We examined the available performance records of public and private wastewater treatment plants (WWTP) in the watershed. We also monitored the EWSU's combined sewer system tributary to Pigeon Creek and examined available operational records. Recommendations are presented below.

7.4.1 Combined Sewer Overflows

We monitored wet weather CSO discharges for eight months. From the water quality data, the waterway is most affected by the discharges of *E. coli* bacteria. That water quality standard is regularly exceeded during wet weather both within and upstream of the CSO discharge area.

The inflow/infiltration monitoring program should be expanded in the CSS. Since more overflows appear to occur in areas with high concentrations of commercial/industrial customers it is recommended that inspection of all commercial and industrial structures be undertaken to identify any additional sources of inflow and infiltration to the sewer system. Efforts should be made to disconnect such direct sources of inflow as far as possible.

Existing flow monitoring efforts should be greatly expanded in order to confirm the capacities of major sanitary sewers and to verify the results of the capacity analyses conducted earlier.

In view of the fact that overflows continue to be significant and are perhaps causing deterioration of Pigeon Creek, Evansville should continue to investigate the feasibility of providing in-line storage in 11 sub-systems and detention/ retention basins at various sites. A gate control system, which would control the non-automated CSOs to Pigeon Creek and the Ohio River, would allow the storage of combined sewerage in the interceptors tributary to the diversions. This gate control system could provide about 154,5000 cubic feet (11.6 MG) of storage. To obtain the maximum storage, available, additional weirs, gates, etc. may be necessary. A study to investigate the feasibility of such a system and the condition of the sewers at the storage sites (to avoid damage from surcharging) is warranted and should be implemented.

Evaluation of a runoff control program to store and control runoff before it enters the combined system is also recommended. The feasibility and effectiveness of this alterative requires development of a system model, scheduled for completion as part of the long-term CSO control plan LTCP. Elements of the LTCP are (USEPA 1995):

1. Characterization, monitoring and modeling activities for selecting and designing effective CSO controls
2. Public participation programming to involve stakeholders in decision-making for long-term controls
3. Consideration of sensitive areas as the highest priority for controlling overflows
4. Evaluation of alternatives to select controls that meet the Clean Water Act requirements
5. Cost and performance considerations
6. Operational plan revisions to include the selected long-term control measures
7. Maximization of treatment at the existing treatment plants for wet weather flows
8. An implementation schedule
9. A post-construction compliance monitoring program

7.4.2 Wastewater Treatment Plants

There are eleven point point discharges permitted for the Pigeon Creek watershed. Five are industrial and six are municipal. In general, the municipal WWTPs in the watershed are not performing well and require expansion, upgrading, and/or additional operator training. Three municipal WWTPs are currently being upgraded, and Fort Branch WWTP should be studied for possible upgrade or expansion.

The Chandler WWTP has a history of poor compliance, but is currently being upgraded, so pollutant discharges from this point source may be reduced in the future.

The Haubstadt WWTP also had a history of poor compliance. We verified this with our sampling program. This WWTP is also being upgraded to reduce wet weather overflows and improve effluent quality.

The Fort Branch WWTP also has noncompliance reports to its records. We measured high coliform bacteria concentrations, high nitrates, and supersaturated dissolved oxygen conditions downsteam of this facility. No plans for expansion or upgrading have been located for this WWTP.

The Elberfeld WWTP has a poor compliance record with numerous noncompliance reports in the EPA's Permit Compliance System database. Elberfeld WWTP is currently being upgraded.

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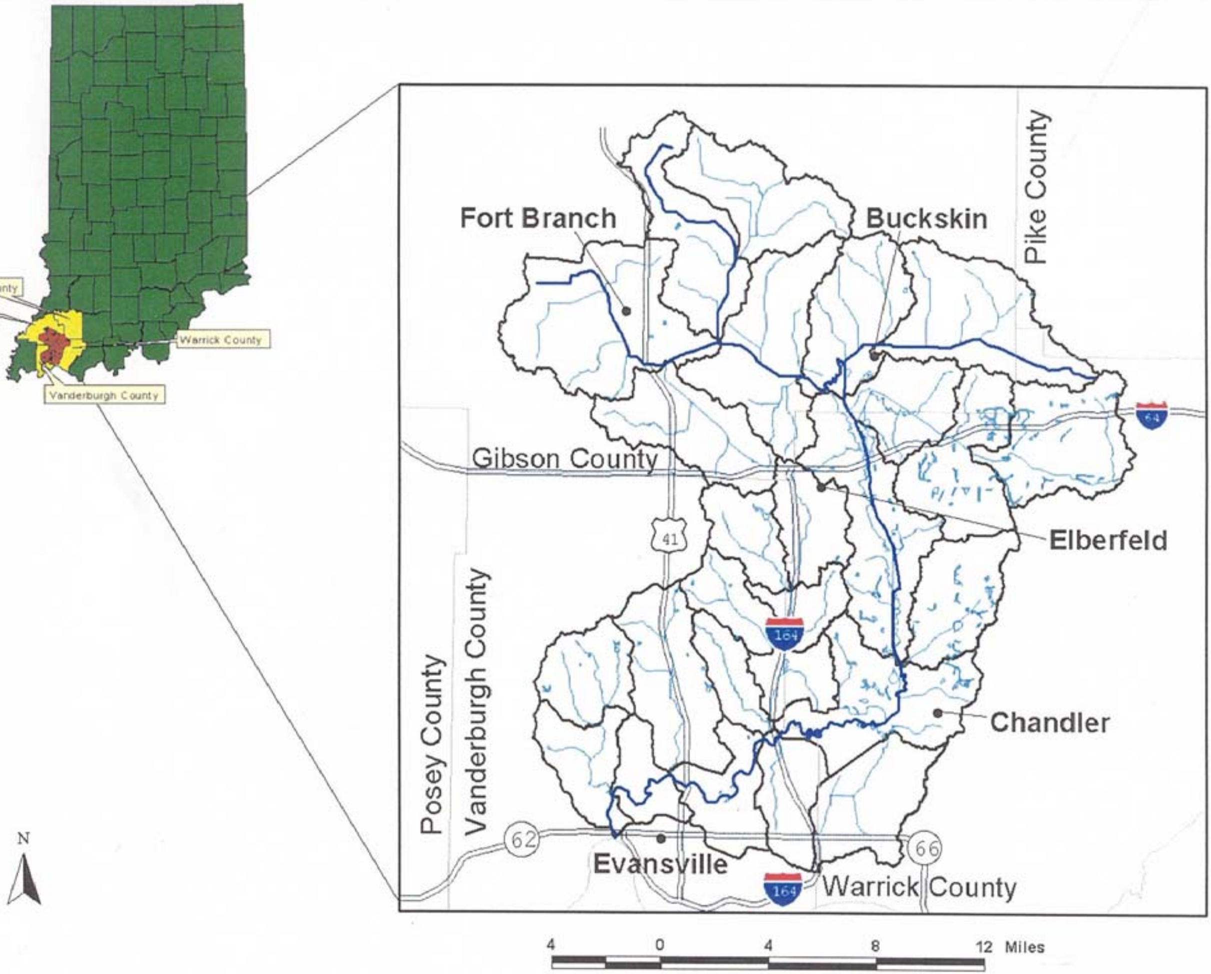
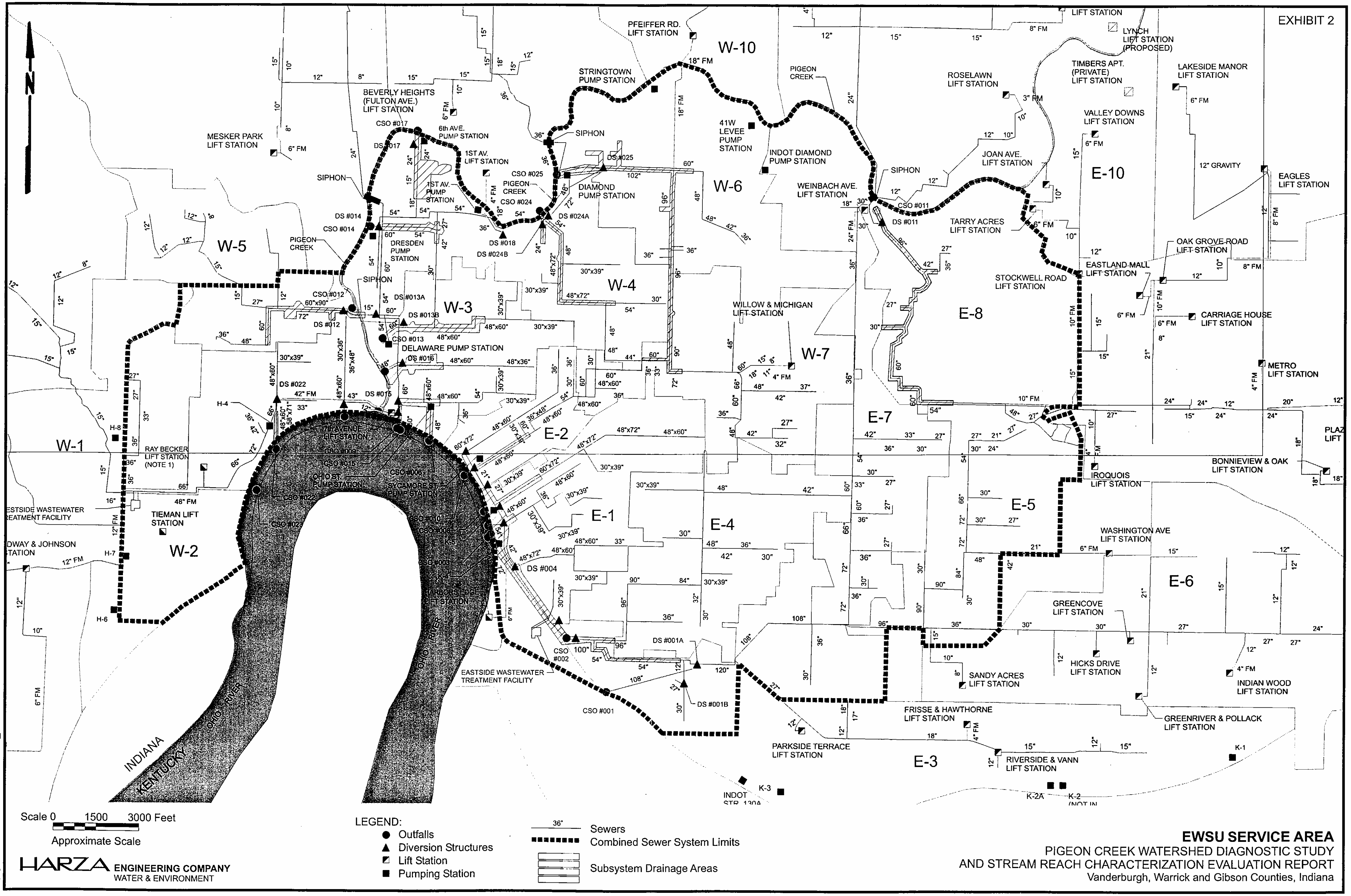
EXHIBITS



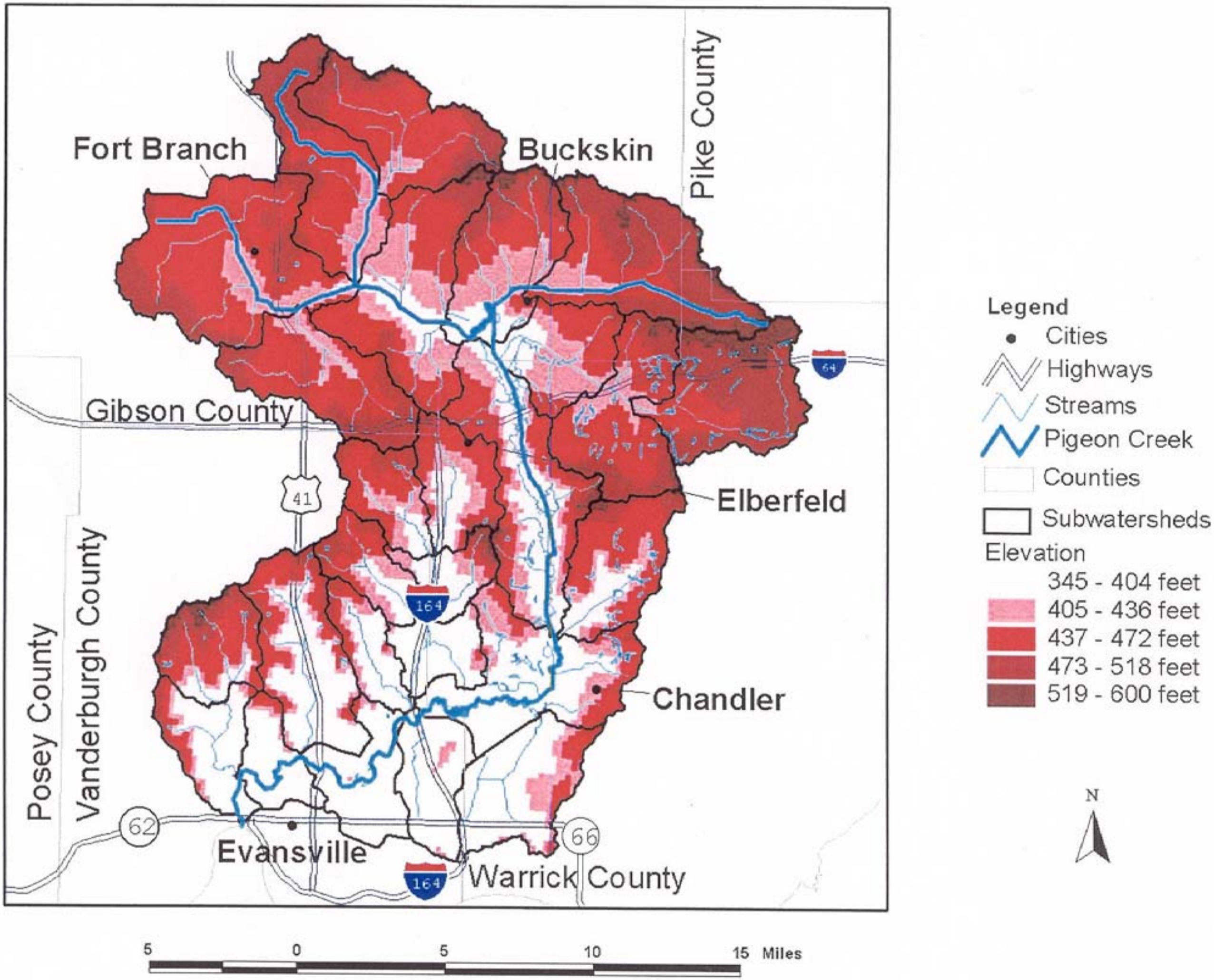
HARZA ENGINEERING COMPANY
WATER & ENVIRONMENT

LOCATION MAP
PIGEON CREEK WATERSHED DIAGNOSTIC STUDY



EWSU SERVICE AREA
PIGEON CREEK WATERSHED DIAGNOSTIC STUDY
AND STREAM REACH CHARACTERIZATION EVALUATION REPORT
Vanderburgh, Warrick and Gibson Counties, Indiana

0:/pigeoncreek/EWSU-Service-Area_exh2.cdr



HARZA ENGINEERING COMPANY
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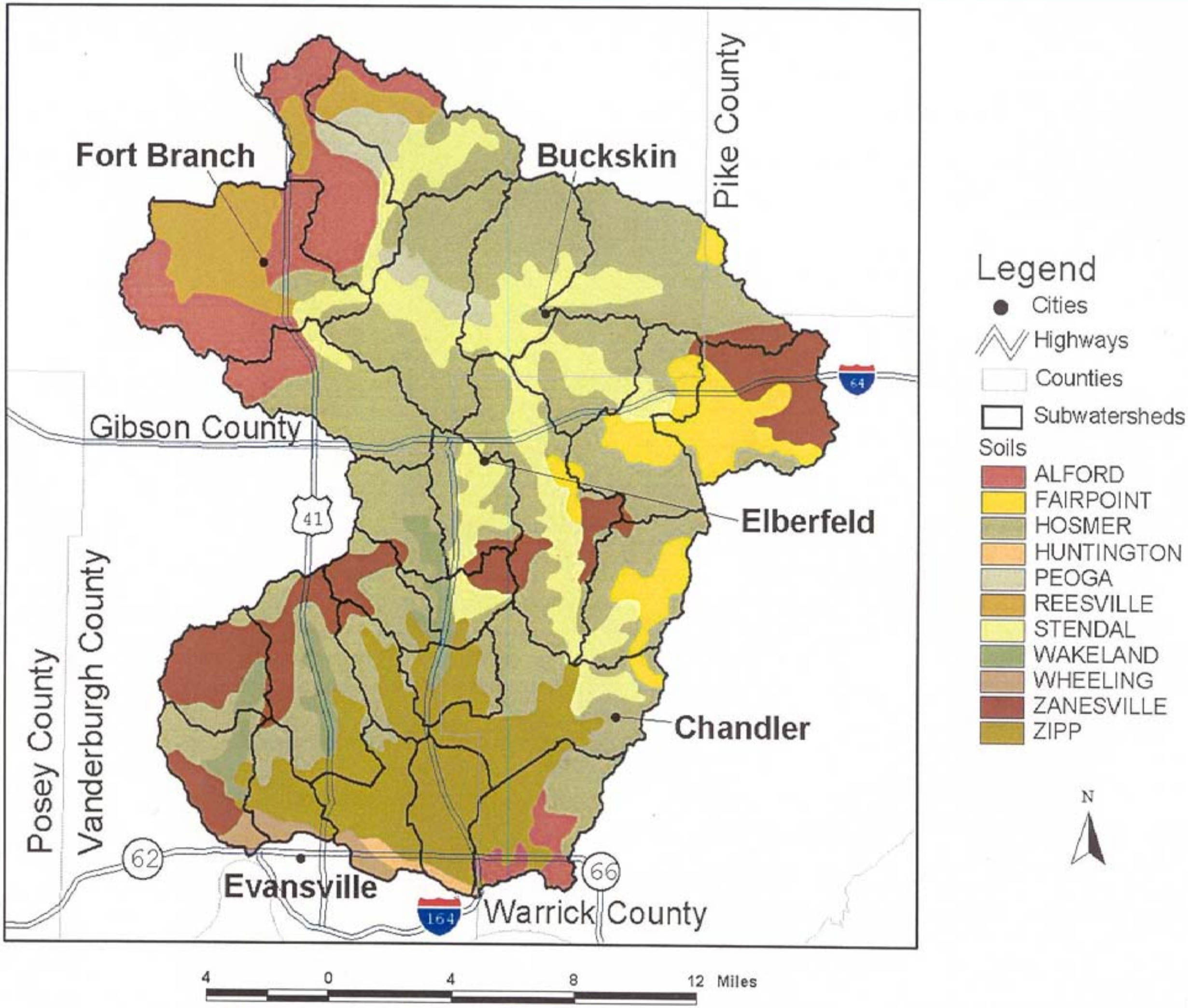
ELEVATION MAP
PIGEON CREEK WATERSHED DIAGNOSTIC STUDY

EXHIBIT 3



HARZA ENGINEERING COMPANY
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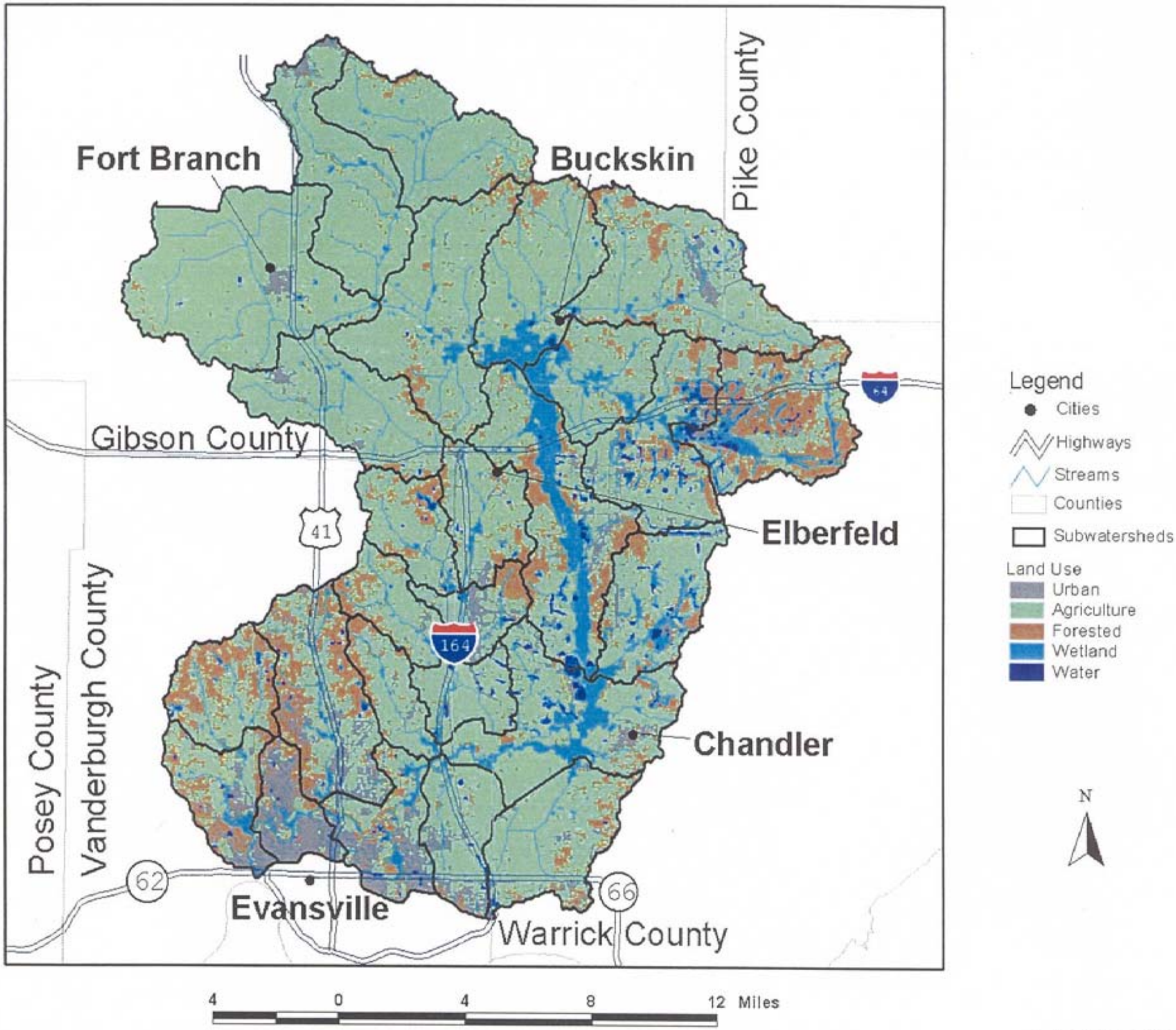
SOIL ASSOCIATIONS MAP
PIGEON CREEK WATERSHED DIAGNOSTIC STUDY

EXHIBIT 4



HARZA ENGINEERING COMPANY
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LAND USE MAP
PIGEON CREEK WATERSHED DIAGNOSTIC STUDY

EXHIBIT 5

Exhibit 6

LAND USE/LAND COVER IN THE PIGEON CREEK WATERSHED
(Source: Indiana Gap Project)

Subwatershed	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
Land Use	**Locust Cr Lower**	**Locust Cr Headwater**	**Kleymeyer Park**	**Harper Ditch**	**Crawford Brandeis Ditch**	**Weinsheimer Ditch**	**Barnes Ditch**	**Dennis Wagner Ditch**	**Firlick Ditch**	**Stubbs Fruedenberg Ditch**	**Schlensker Ditch**	**Little Pigeon Creek**	**Unnamed Tributary to Blue Grass Creek**
Other Non-vegetated	138.1	34.2	76.9	392.6	492.4	246.1	625.4	337.7	64.8	973.8	56.8	701.7	135.8
Urban High Density	494.3	28.6	1183.2	710.2	102.8	49.7	82.4	0.0	0.0	24.1	35.1	270.0	3.2
Urban Low Density	714.4	111.9	1473.3	1341.2	540.4	351.7	264.3	4.9	123.8	30.8	98.4	1146.1	12.8
Agriculture Row Crop	1228.1	1198.2	28.7	1208.3	3736.8	5533.5	5426.6	2287.6	1777.4	1345.9	1865.4	1826.5	2516.7
Pasture/Grassland	1300.6	1772.9	387.6	1153.1	619.9	1613.4	3354.7	1303.7	1207.1	657.8	1328.4	2669.2	1274.7
Shrubland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Woodland	14.5	15.2	0.2	8.3	0.0	15.5	96.9	10.9	16.1	16.0	3.0	65.4	0.0
Forest Deciduous	1770.9	3108.2	780.7	1120.0	228.3	1104.6	707.5	52.4	796.9	673.2	1066.2	4033.8	1010.9
Forest Evergreen	10.2	42.8	6.3	2.8	0.0	0.0	162.2	0.0	0.0	0.0	9.9	37.6	29.6
Forest Mixed	0.0	0.0	5.5	49.7	2.4	9.8	94.0	0.0	26.7	12.2	34.9	38.0	46.8
Wetland Forest	253.2	61.6	162.1	453.5	116.8	104.3	1585.7	125.0	138.2	115.5	89.4	264.5	86.6
Wetland Woodland	11.1	17.7	9.8	0.0	0.0	0.0	3.3	0.0	0.0	0.0	0.0	7.5	0.0
Wetland Shrubland	25.5	15.2	20.9	0.0	2.5	0.0	140.0	0.0	0.0	0.0	0.0	26.2	0.0
Wetland Herbaceous	29.0	0.0	3.5	14.3	0.0	39.2	139.0	2.8	4.5	26.9	0.0	15.1	19.4
Wetland Sparsely Vegetated	60.8	4.2	18.7	17.6	0.0	10.3	82.7	0.0	0.0	8.0	11.6	0.0	15.7
Water	50.2	85.9	19.1	72.5	60.9	24.4	451.5	105.8	15.2	26.7	22.6	107.7	94.4
Total	6101.0	6496.6	4176.4	6544.1	5903.2	9102.6	13216.2	4230.7	4170.8	3910.9	4621.7	11209.2	5246.6

Subwatershed	14	15	16	17	18	19	20	21	22	23	24	25	26	
Land Use	**Blue Grass Cr Hdwtrs**	**Clear Branch**	**Squaw Creek**	**Big Creek - Little Creek**	**Big Creek Headwaters**	**Big Creek - Wye**	**Smith Fork Headwaters**	**Smith Fork - Halfmoon Creek**	**Snake Run**	**Hurricane Ditch Creek**	**West Fork Creek**	**Clear Fork Ditch**	**Sand Creek - Muddy Fork Ditch**	**Total**
Other Non-vegetated	389.0	820.2	573.9	792.2	436.9	37.7	978.3	79.5	151.8	195.7	102.7	48.6	37.2	8,920
Urban High Density	34.9	7.6	10.1	5.2	20.7	4.9	4.6	8.1	0.0	114.1	136.9	173.7	7.6	3,512
Urban Low Density	74.4	14.4	0.0	10.8	20.2	6.6	45.9	19.2	38.4	161.9	351.3	327.1	50.8	7,335
Agriculture Row Crop	3116.7	3689.0	1467.2	1995.6	1553.2	3670.7	6986.8	7078.4	10979.6	7753.7	16784.6	9113.0	8887.2	113,055
Pasture/Grassland	1443.0	3073.8	3992.2	4103.9	2243.6	1375.7	3751.7	1337.8	1577.3	1477.5	1333.6	1137.1	1237.5	46,728
Shrubland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-
Woodland	19.1	322.8	219.9	449.1	751.3	45.6	188.9	20.3	7.0	3.9	5.3	15.9	3.3	2,315
Forest Deciduous	877.8	2877.3	930.6	1247.8	2905.2	577.1	2206.5	785.5	1214.2	581.4	236.1	333.1	879.8	32,106
Forest Evergreen	6.9	0.0	78.8	161.7	803.2	0.0	0.0	0.0	0.0	0.0	2.1	0.0	0.0	1,354
Forest Mixed	5.4	70.6	70.2	480.4	1327.2	13.7	25.7	11.3	9.2	3.7	0.0	0.0	1.9	2,339
Wetland Forest	166.2	2526.7	529.4	461.5	792.2	1056.2	193.8	1001.2	448.3	101.7	66.9	168.8	79.5	11,149
Wetland Woodland	0.0	18.1	3.2	0.0	4.7	3.7	0.0	0.0	0.0	3.1	5.7	0.0	0.0	88
Wetland Shrubland	8.0	403.6	79.2	52.8	84.0	191.3	0.0	168.0	1.7	0.0	5.5	14.9	3.7	1,243
Wetland Herbaceous	7.3	112.5	92.2	100.2	120.9	50.1	22.0	72.9	10.2	3.0	3.5	21.4	10.0	920
Wetland Sparsely Vegetated	7.4	170.9	140.6	48.0	100.8	52.0	44.0	17.8	4.5	0.0	0.0	0.0	0.0	816
Water	34.0	474.3	355.2	614.8	439.4	31.5	125.1	72.2	6.9	20.1	30.1	4.9	1.4	3,347
Total	6189.9	14581.9	8542.7	10524.0	11603.5	7116.8	14573.2	10672.1	14449.1	10419.8	19064.4	11358.6	11199.8	235,226

WATER QUALITY DATA
(Source: STORET, EWSU, this study)

Site	Waterbody	Description	Longitude	Latitude	SampleDate	DissolvedO2	pH	WaterTemp	SpecificConductivity	Turbidity	Chloride	Ammonia N	Nitrate+nitrite N	TKN	Phosphorus	TSS	E coli (/100mL)
381110087211700	Big Creek	Near Lynnville, IN Site 458	872117	381110	5/23/79		7.84	21.7	3400								
381110087211700	Big Creek	Near Lynnville, IN Site 458	872117	381110	10/16/79		7.8	13	4500								
380258087285600	Bluegrass Creek	Near Daylight, IN Site #268	872856	380258	5/30/79		7.68	18.9	590								
380258087285600	Bluegrass Creek	Near Daylight, IN Site #268	872856	380258	10/16/79		6.8	12	760								
SQC-06	Peabody Squaw Creek	625 West Road	872148	380512	3/4/75			4	2400							13	
OHP040-0010	Pigeon Creek	Diamond Avenue (US 66)	873358.87	375959.13	6/26/00	6.2	7.7	25	548	40.7							
OHP040-0010	Pigeon Creek	Diamond Avenue (US 66)	873358.87	375959.13	8/8/00	4.8	7.1	24	227	287.4	13.5						
OHP040-0004	Pigeon Creek	First Avenue	873429	375944	4/20/99	10.5	8.2	13	1288	22.1		<0.1	1.5	0.6	0.15	28	
OHP040-0004	Pigeon Creek	First Avenue	873429	375944	5/12/99	8.1	7.9	21	1080	23.4		0.1	2	0.5	0.13	53	
OHP040-0004	Pigeon Creek	First Avenue	873429	375944	6/9/99	4.5	7.8	28	840	133.0		0.2	3.6	1.7	0.41	110	
OHP040-0004	Pigeon Creek	First Avenue	873429	375944	7/21/99	7.2	8.1	31	760	24.2		0.3	0.8	1.1	0.29	19	
OHP040-0004	Pigeon Creek	First Avenue	873429	375944	8/12/99	5.9	7.9	25	2080	11.8		0.1	0.2	0.7	0.2	11	
OHP040-0004	Pigeon Creek	First Avenue	873429	375944	9/8/99	6.6	8.0	26	2050	14.8		0.1	<0.1	0.7	0.15	16	
OHP040-0004	Pigeon Creek	First Avenue	873429	375944	10/13/99	6.0	7.6	19		28.2		0.2	0.9	0.8	0.33	38	
OHP040-0004	Pigeon Creek	First Avenue	873429	375944	11/9/99	7.0	8.3	16	2350	35.1		<0.1	<0.1	0.7	0.2	12	
OHP040-0004	Pigeon Creek	First Avenue	873429	375944	12/9/99	10.2	8.3	9	2470	11.6		<0.1	0.2	0.6	0.15	12	
OHP040-0004	Pigeon Creek	First Avenue	873429	375944	1/12/00	10.7	7.9	8	1254	38.9		0.2	1.4	0.7	0.13	27	
OHP040-0004	Pigeon Creek	First Avenue	873429	375944	2/22/00	9.7	8.1	7	392	148.0		0.1	1.7	1.2	0.41	82	
OHP040-0004	Pigeon Creek	First Avenue	873429	375944	3/15/00	10.4	8.1	13	1025	31.8		0.2	2.2		0.1	43	
OHP040-0004	Pigeon Creek	First Avenue	873429	375944	4/13/00	7.7	7.5	14	950	37.2		0.1	1.9	0.8	0.12	26	
OHP040-0004	Pigeon Creek	First Avenue	873429	375944	5/4/00	5.9	7.7	19	1490	88.2		0.2	0.8	0.9	0.21	93	
OHP040-0004	Pigeon Creek	First Avenue	873429	375944	6/8/00	6.2	7.7	19	1600	30.1		0.2	1.6	0.9	0.18	51	
OHP040-0004	Pigeon Creek	First Avenue	873429	375944	7/10/00	7.9	7.9	30	1086	41.4							
OHP040-0004	Pigeon Creek	First Avenue	873429	375944	8/7/00	4.3	7.6	26	571	112.0							
OHP040-0004	Pigeon Creek	First Avenue	873429	375944	9/6/00	6.7	7.5	21	1016	23.7							
EWSU	Pigeon Creek	Franklin Street			11/21/91	5.7		15							0.26	84	200
EWSU	Pigeon Creek	Franklin Street			12/4/91	10.5		3							0.38	370	600
EWSU	Pigeon Creek	Franklin Street			12/11/91	7.7		7							0.15	37	1000
EWSU	Pigeon Creek	Franklin Street			1/9/92	10.8		7							0.21	27	3000
EWSU	Pigeon Creek	Franklin Street			1/30/92	10.4		4							0.08	18	0
EWSU	Pigeon Creek	Franklin Street			2/13/92	14.4		4							0.2	38	4400
EWSU	Pigeon Creek	Franklin Street			2/27/92	10.7		7							0.2	20	0
EWSU	Pigeon Creek	Franklin Street			3/5/92	13.2		13							0.1	26	0
EWSU	Pigeon Creek	Franklin Street			3/18/92	11.8		8							0.31	46	14000
EWSU	Pigeon Creek	Franklin Street			4/8/92	8.0		13							0.55	24	100
EWSU	Pigeon Creek	Franklin Street			9/18/92	7.4		25							0.04	21	4000
EWSU	Pigeon Creek	Franklin Street			10/8/92	7.1		19							0.11	26	920
EWSU	Pigeon Creek	Franklin Street			10/22/92	6.8		16							0.17	36	200
EWSU	Pigeon Creek	Franklin Street			11/12/92	7.1		13							1.36	370	4600
EWSU	Pigeon Creek	Franklin Street			11/24/92	5.7		12							0.68	126	5810
EWSU	Pigeon Creek	Franklin Street			3/3/93	9.4	7.6	8			27				0.34	86	5700
EWSU	Pigeon Creek	Franklin Street			5/18/93	5.6	7.4	20			39				0.55	246	5200
EWSU	Pigeon Creek	Franklin Street			8/25/93	6.4	7.4	30			48.6				0.18	25	800
EWSU	Pigeon Creek	Franklin Street			11/17/93	6.8	6.6	14			8.2				1.23	143	6700
EWSU	Pigeon Creek	Franklin Street			3/9/94	10.3	7.3	8			17.6				0.35	17	30
EWSU	Pigeon Creek	Franklin Street			6/1/94	8.3	8.1	25							0.1	16	106
EWSU	Pigeon Creek	Franklin Street			3/13/95							0.21	0.5		0.23		120
EWSU	Pigeon Creek	Green River Road Bridge			11/21/91	6.6		14							0.27	62	6500
EWSU	Pigeon Creek	Green River Road Bridge			12/4/91	10.8		4							1.23	281	500
EWSU	Pigeon Creek	Green River Road Bridge			12/11/91	8		7							0.21	27	0
EWSU	Pigeon Creek	Green River Road Bridge			1/9/92	11		5							0.18	27	108
EWSU	Pigeon Creek	Green River Road Bridge			1/30/92	14.2		6							0.03	5	0
EWSU	Pigeon Creek	Green River Road Bridge			2/13/92	12.4		4							0.18	37	0
EWSU	Pigeon Creek	Green River Road Bridge			2/27/92	12.1		7							0.13	20	0
EWSU	Pigeon Creek	Green River Road Bridge			3/5/92	7.7		14							0.26	46	0
EWSU	Pigeon Creek	Green River Road Bridge			3/18/92	10		9							0.83	285	16000

WATER QUALITY DATA
(Source: STORET, EWSU, this study)

Site	Waterbody	Description	Longitude	Latitude	SampleDate	DissolvedO2	pH	WaterTemp	SpecificConductivity	Turbidity	Chloride	Ammonia N	Nitrate+nitrite N	TKN	Phosphorus	TSS	E coli (/100mL)
EWSU	Pigeon Creek	Green River Road Bridge			4/8/92	8.4		14							0.4	59	100
EWSU	Pigeon Creek	Green River Road Bridge			9/18/92	4.3		22							0.19	74	0
EWSU	Pigeon Creek	Green River Road Bridge			10/8/92	7.2		19							0.08	26	880
EWSU	Pigeon Creek	Green River Road Bridge			10/22/92	6.6		16							0.14	19	90
EWSU	Pigeon Creek	Green River Road Bridge			11/12/92	7		13							1.12	378	2400
EWSU	Pigeon Creek	Green River Road Bridge			11/24/92	5.8		12							0.8	118	4600
EWSU	Pigeon Creek	Green River Road Bridge			3/3/93	9	7.37	8			14				0.37	99	3100
EWSU	Pigeon Creek	Green River Road Bridge			5/18/93	5.2	7.32	19			54.9				1.38	35	8800
EWSU	Pigeon Creek	Green River Road Bridge			8/25/93	3.8	7.18	28			67.8				0.62	48	900
EWSU	Pigeon Creek	Green River Road Bridge			11/17/93	6.5	6.53	12			9.2				1.09	178	4900
EWSU	Pigeon Creek	Green River Road Bridge			3/9/94	9.8	7.52	8			265.7				0.18	25	50
EWSU	Pigeon Creek	Green River Road Bridge			6/1/94	7.4	8.14	25							0.13	40	190
EWSU	Pigeon Creek	Green River Road Bridge			3/13/95							0.15	1.9		0.22		650
OHP040-0005	Pigeon Creek	Lynch Road	872941.38	380047.49	6/26/00	7.8	7.3	26	778	40.7							
OHP040-0005	Pigeon Creek	Lynch Road	872941.38	380047.49	8/7/00	4.3	7.2	26	683	84.0	36.6						
174346	Pigeon Creek	Maryland Street	873528	375908	10/11/73							0.28			2.76		
174346	Pigeon Creek	Maryland Street	873528	375908	11/15/73							2.1			0.3		
174346	Pigeon Creek	Maryland Street	873528	375908	12/12/73							8			10		
174346	Pigeon Creek	Maryland Street	873528	375908	5/23/74			22	500			0.36		0.94	0.299	350	
174346	Pigeon Creek	Maryland Street	873528	375908	6/20/74			24	1170			0.37		1.7	0.359	225	
381237087262900	Pigeon Creek	Near Buckskin, IN Site 197	872629	381237	5/30/79		8.46	22.8	670								
381237087262900	Pigeon Creek	Near Buckskin, IN Site 197	872629	381237	10/16/79		8.4	13	950								
OHP040-0012	Pigeon Creek	NW 2nd Street Bridge (Ohio Street)	873515.06	375834.28	6/26/00	6.5	7.4	26	511	41.5							
OHP040-0012	Pigeon Creek	NW 2nd Street Bridge (Ohio Street)	873515.06	375834.28	8/8/00	4.4	7.1	24	314	258	15.6						
EWSU	Pigeon Creek	Oak Hill Road	873129.84	375946.32	11/21/91	6.3		15							0.32	80	
EWSU	Pigeon Creek	Oak Hill Road	873129.84	375946.32	12/4/91	10.8		4							0.6	301	300
EWSU	Pigeon Creek	Oak Hill Road	873129.84	375946.32	12/11/91	8.1		8							0.2	34	0
EWSU	Pigeon Creek	Oak Hill Road	873129.84	375946.32	1/9/92	10.6		5							0.1	24	0
EWSU	Pigeon Creek	Oak Hill Road	873129.84	375946.32	1/30/92	13.0		3							0.01	16	0
EWSU	Pigeon Creek	Oak Hill Road	873129.84	375946.32	2/13/92	12.4		4							0.04	21	600
EWSU	Pigeon Creek	Oak Hill Road	873129.84	375946.32	2/27/92	11.9		7							0.2	22	1,000
EWSU	Pigeon Creek	Oak Hill Road	873129.84	375946.32	3/5/92	6.4		14							0.77	72	0
EWSU	Pigeon Creek	Oak Hill Road	873129.84	375946.32	3/18/92	10.0		9							0.26	146	5,000
EWSU	Pigeon Creek	Oak Hill Road	873129.84	375946.32	4/8/92	8.2		14							0.1	64	200
EWSU	Pigeon Creek	Oak Hill Road	873129.84	375946.32	9/18/92	4.0		23							0.15	56	0
EWSU	Pigeon Creek	Oak Hill Road	873129.84	375946.32	10/8/92	6.8		20							0.21	55	760
EWSU	Pigeon Creek	Oak Hill Road	873129.84	375946.32	10/22/92	6.3		15							0.16	46	200
EWSU	Pigeon Creek	Oak Hill Road	873129.84	375946.32	11/12/92	6.6		12							0.46	157	2,800
EWSU	Pigeon Creek	Oak Hill Road	873129.84	375946.32	11/24/92	5.7		11							0.51	105	6,700
EWSU	Pigeon Creek	Oak Hill Road	873129.84	375946.32	3/3/93	10.4	7.2	6			23				0.31	293	4,600
EWSU	Pigeon Creek	Oak Hill Road	873129.84	375946.32	5/18/93	5.1	7.4	19			22.4				0.2	814	2,400
EWSU	Pigeon Creek	Oak Hill Road	873129.84	375946.32	8/25/93	3.8	6.7	29			72.2				0.71	96	70,000
EWSU	Pigeon Creek	Oak Hill Road	873129.84	375946.32	11/17/93	6.5	6.7	16			8.1				1.37	141	5,300
EWSU	Pigeon Creek	Oak Hill Road	873129.84	375946.32	3/9/94	9.7	7.9	10			32.3				0.15	27	40
EWSU	Pigeon Creek	Oak Hill Road	873129.84	375946.32	6/1/94	6.7	8.3	25							0.28	76	210
EWSU	Pigeon Creek	Oak Hill Road	873129.84	375946.32	3/13/95							0.22	2.1		0.23		250
OHP040-0006	Pigeon Creek	Oak Hill Road	873129.84	375946.32	6/26/00	6.0	7.5	25	712	40.6							
OHP040-0006	Pigeon Creek	Oak Hill Road	873129.84	375946.32	8/7/00	4.2	7.2	25	673	82.3	25.9						
174350	Pigeon Creek	Stringtown Road	873317	380028	1/31/73			2.5	620			0.28				27	
EWSU	Pigeon Creek	Stringtown Road	873318.28	380028.51	3/3/93	12.3	7.3	7			19				0.46	368	2200
EWSU	Pigeon Creek	Stringtown Road	873318.28	380028.51	5/18/93	6.3	7.4	18			19.4				0.92	367	5100
EWSU	Pigeon Creek	Stringtown Road	873318.28	380028.51	8/25/93	3.8	7.2	30			77.6				1.83	29	110,000
EWSU	Pigeon Creek	Stringtown Road	873318.28	380028.51	11/17/93	6.4	6.7	13			9				1.35	178	3900
EWSU	Pigeon Creek	Stringtown Road	873318.28	380028.51	3/9/94	9.9	7.7	9			34.2				0.23	22	70
EWSU	Pigeon Creek	Stringtown Road	873318.28	380028.51	6/1/94	7.8	8.1	26							0.22	40	280
EWSU	Pigeon Creek	Stringtown Road	873318.28	380028.51	3/13/95							0.18	1.9		1.53		270

WATER QUALITY DATA
(Source: STORET, EWSU, this study)

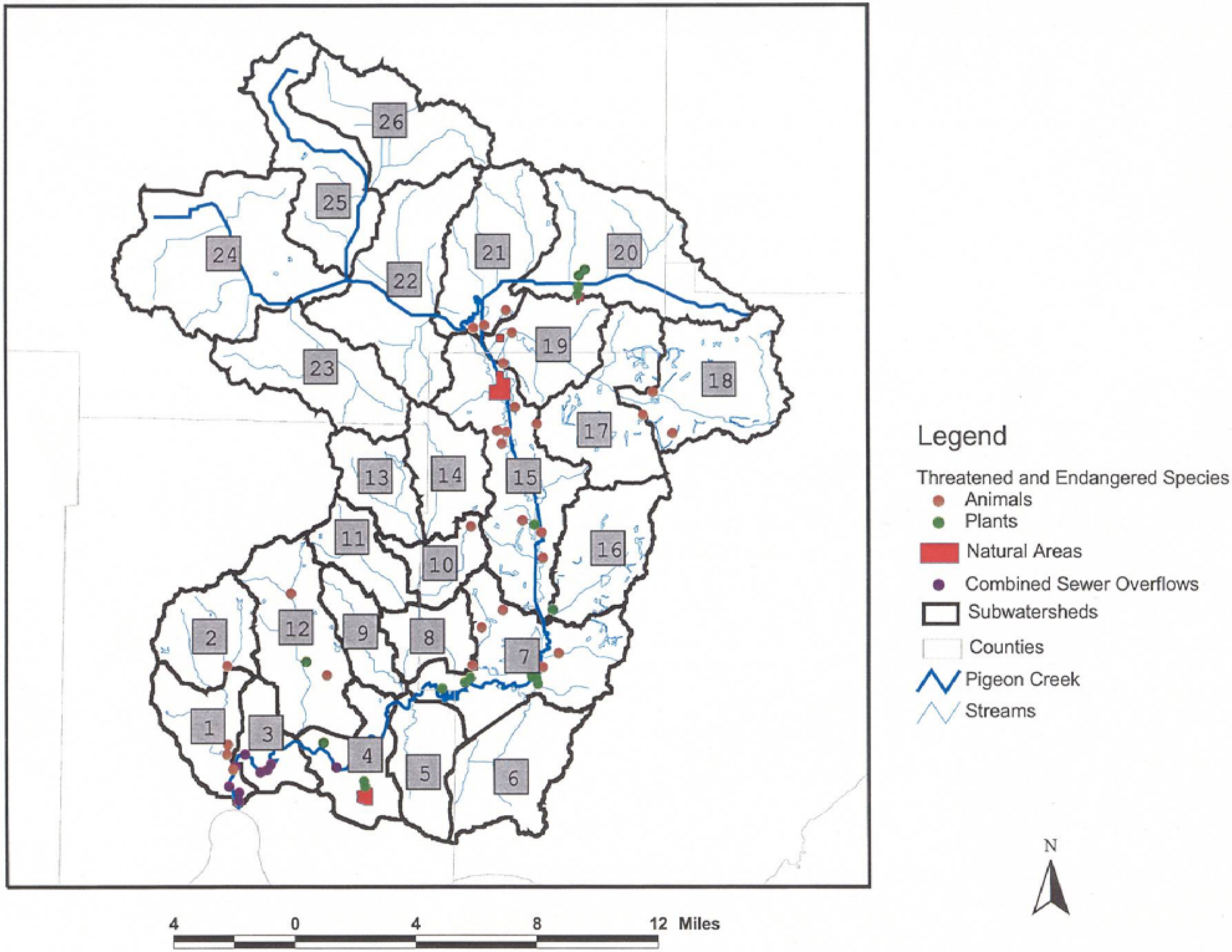
Site	Waterbody	Description	Longitude	Latitude	SampleDate	DissolvedO2	pH	WaterTemp	SpecificConductivity	Turbidity	Chloride	Ammonia N	Nitrate+nitrite N	TKN	Phosphorus	TSS	E coli (/100mL)
OHP040-0008	Pigeon Creek	Stringtown Road	873318.28	380028.51	6/26/00	5.3	7.6	25	574	40.6							
OHP040-0008	Pigeon Creek	Stringtown Road	873318.28	380028.51	8/8/00	4.5	7.0	24	231	228	12.2						
174352	Pigeon Creek	US 41	873220.12	380014.06	1/31/73			2.5	640			0.28				28	
OHP040-0007	Pigeon Creek	US 41 South, Diamond Avenue Exit Ramp	873220.12	380014.06	6/26/00	6.5	7.6	25	644	40.7							
OHP040-0007	Pigeon Creek	US 41 South, Diamond Avenue Exit Ramp	873220.12	380014.06	8/7/00	4.1	7.2	25	655	86.4	24.6						
381412087200700	Smith Fork	Near Lynnville, IN Site 700	872007	381412	3/18/81		7.9	3.9	805								
381412087200700	Smith Fork	Near Lynnville, IN Site 700	872007	381412	5/7/81		9.3	20	735								
381412087200700	Smith Fork	Near Lynnville, IN Site 700	872007	381412	6/4/81		8.1	25.3	750								
381412087200700	Smith Fork	Near Lynnville, IN Site 700	872007	381412	7/9/81		7.5	30.1	1370								
381346087184400	Smith Fork	Near Spurgeon, IN Site 1000	871844	381346	3/18/81		8.3	8.3	1110								
381346087184400	Smith Fork	Near Spurgeon, IN Site 1000	871844	381346	8/6/81		6.9	26.3	315								
381355087195400	Smith Fork Tributary	Near Buckskin, IN Site 800	871954	381355	3/18/81		7.7	4.9	515								
381354087183500	Smith Fork Tributary	Near Mackey, IN Site 1100	871835	381354	3/18/81		6.9	11.2	2400								
380530087215500	Squaw Cr Tributary	Near Booneville, IN Site 461	872155	380530	5/24/79		8.1	16.4	1730								
380530087215500	Squaw Cr Tributary	Near Booneville, IN Site 461	872155	380530	10/16/79		7.6	14.5	2500								
380531087211200	Squaw Creek	Near Booneville, IN Site 460	872112	380531	5/24/79		8.23	19.9	2660								
380531087211200	Squaw Creek	Near Booneville, IN Site 460	872112	380531	10/16/79		8	15.5	3000								
380531087211200	Squaw Creek	Near Booneville, IN Site 460	872112	380531	1/28/80		8.6	3.1	2780								
380531087211200	Squaw Creek	Near Booneville, IN Site 460	872112	380531	2/25/80		8	3	2810								
380531087211200	Squaw Creek	Near Booneville, IN Site 460	872112	380531	3/27/80		7.7	11.1	2830								
380531087211200	Squaw Creek	Near Booneville, IN Site 460	872112	380531	4/24/80		7.9	22.3	2860								
380531087211200	Squaw Creek	Near Booneville, IN Site 460	872112	380531	5/29/80		8.1	26.5	2770								
380531087211200	Squaw Creek	Near Booneville, IN Site 460	872112	380531	6/18/80		8.1	26	2620								
380531087211200	Squaw Creek	Near Booneville, IN Site 460	872112	380531	7/16/80		8	32.2	2680								
380531087211200	Squaw Creek	Near Booneville, IN Site 460	872112	380531	8/13/80		7.8	28.3	2740								

WATER QUALITY DATA
(Source: STORET, EWSU, this study)

Site	Water body	Date	Time	Temp (C)	Conductivity (umhos)	pH	DO (mg/L)	% DO Saturation	Ammonia N (mg/L)	Total Kjeldahl N (mg/L)	Nitrate N (mg/L)	Phosphorus (mg/L)	BOD (mg/L)	Suspended solids (mg/L)	E. coli (/100 mL)
PC1	Pigeon Creek	08/06/1999	15:40	31	889	8.87	5.53	74	0.68	1.0	0.68	0.41	<2.8	9	12
PC2	Pigeon Creek	08/07/1999	8:30	27.6	1980	8.58	5.15	65	0.33	1.8	0.41	0.66	<2.1	25	36
PC3	Pigeon Creek	08/07/1999	7:45	25.4	2117	8.5	4.08	50	0	1.0	<0.05	0.68	<2.1	13	92
PC4	Pigeon Creek	08/07/1999	9:15	28.3	2144	8.65	4.89	63	0.95	1.1	<0.05	0.67	<2.1	13	70
PC5	Pigeon Creek	08/07/1999	9:45	27.8	2153	8.53	5.08	65	0.15	1.4	<0.05	0.68	<2.1	14	60
PC6	Pigeon Creek	08/09/1999	8:45	24.9	1599	8.45	1.41	17	2.88	2.0	0.68	0.73	3.1	13	24000
PC7	Pigeon Creek	08/09/1999	10:45	24.9	1776	8.44	2.46	30	0.38	<1.0	0.34	0.7	<3.0	36	16000
PC8	Pigeon Creek	08/09/1999	14:30	25.6	2136	8.49	3.02	37	2.27	2.1	0.49	0.78	<3.0	68	1000
PC8 dup	Pigeon Creek	08/09/1999							0.44	2.1	0.53	0.78	<3.0	63	300
PC9	Pigeon Creek	08/10/1999	10:15	27.6	1641	8.56	4.51	57	0.41	1.7	1.40	0.98	<2.8	72	210
PC11	Pigeon Creek	08/11/1999	11:30	26	1900		5.3	65	1.01	<1.0	0.68	0.44	<2.8	34	180
PC12	Pigeon Creek	08/12/1999	16:00	29.5	1500	8.37	7.4	97	0.67	2.5	0.54	0.16	<2.8	23	295
PC12 dup	Pigeon Creek	08/12/1999							0.54	1.1	0.8	0.19	<2.8	26	300
PC13	Pigeon Creek	08/13/1999	11:00	28	1250		6.8	87	1.37	<1.0	0.65	0.21	<5.0	35	420
PC14	Pigeon Creek	08/15/1999	13:05	28	590	8.66	16	204	0.73	<1.0	1.60	0.48	<3.0	20	8
PC15	Pigeon Creek	08/05/1999	16:30	21.5	436	8.78	5.9	67	0.45	2.8	1.60	0.47	<2.8	8	0
PC16	Pigeon Creek	08/05/1999	11:15	27.5	720	7.90	4.99	63	2.75	2.8	<0.05	0.4	<2.8	12	0
LC1	Locust Creek	08/08/1999	13:00	23.6	412	9.02	3.01	35	0.55	2.0	<0.05	0.59	<3.0	27	880
LC2	Locust Creek	08/10/1999	8:00	23.7	394	8.51	2.77	33	1.14	3.2	<0.05	0.66	<5.0	140	610
LP1	Little Pigeon Creek	08/08/1999	11:15	24.1	201	8.82	3.38	40	0.34	2.1	1.20	0.6	4.3	51	1100
LP2	Little Pigeon Creek	08/08/1999	8:30	23.5	327	8.43	1.57	18	0.61	2.4	<0.05	0.59	<3.0	9	320
BC1	Bluegrass Creek	08/09/1999	16:15	24.2	1946	8.56	4.87	58	1.92	<1.0	<0.05	0.56	<3.0	5	3500
BC2	Bluegrass Creek	08/10/1999	9:30	33.9	2191	9.35	6.34	83	1.15	1.4	<0.05	0.55	<3.0	19	540
BC3	Bluegrass Creek	08/11/1999	8:30	25.9	478	8.59	3.63	45	1.6	<1.0	<0.05	0.29	<2.8	51	27
WD1	Weinsheimer Ditch	08/12/1999	8:30	25.5	400	7.63	2.8	34	1.55	<1.0	<0.05	0.12	3.7	69	200
SD1	Stollberg Ditch	08/13/1999	8:35	25	1130		2.1	25	1.13	4.6	5.40	2.9	7.1	70	70
UN1	Unnamed Tributary	08/12/1999	12:05	28	1120	8.00	6.5	83	0.96	1.1	<0.05	0.08	<2.8	61	43
SC1	Squaw Creek	08/11/1999	15:30	25	3800		7.7	93	1.04	1.8	<0.05	0.3	<2.8	8	67
BG1	Big Creek	08/14/1999	8:30	28.5	3225	8.26	5.6	72	0.36	<1.0	<0.05	0.05	<2.8	11	98
BG2	Big Creek	08/13/1999	14:45	27.5	3200		7	89	0.26	<1.0	<0.05	0.02	<5.0	60	10
SF1	Smith Fork	08/14/1999	16:00	25	1400		11.3	137	0.49	1.3	<0.05	0.07	<2.8	5	110
SF2	Smith Fork	08/14/1999	13:45	29	1780	8.60	9.8	127	0.22	<1.0	<0.05	0.07	<2.8	10	25
SF3	Smith Fork	08/14/1999	10:10	28	2000	8.33	7.4	95	0.35	<1.0	<0.05	0.09	<2.8	2	54
WF1	West Fork	08/15/1999	9:45	24	830	8.81	13.5	160	0.44	<1.0	2.40	1.4	<3.0	24	230
WF2	West Fork	08/15/1999	12:15	28	960	9.14	0	256	0.56	<1.0	6.70	0.6	<3.0	20	540
WF3	West Fork	08/15/1999	8:40	17	700	8.12	6.7	69	0.42	1.4	<0.05	0.06	<3.0	22	270
HC1	Hurricane Creek	08/15/1999	14:10	30	1060	8.73	15.2	201	0.37	<1.0	3.0	7.2	<3.0	14	39
HC1 dup	Hurricane Creek	08/15/1999							0.28	1.8	3.1	6.9	<3.0	38	340
SA1	Sand Creek	08/06/1999	11:30	26.6	488	8.75	5.84	66	0.56	<1.0	<0.05	0.43	<2.8	10	5
PC1	Pigeon Creek	5/11/2000		22	1,192	7.82	17	206	0.33	<1.0	0.87	0.4	<2.5	32	50
PC2	Pigeon Creek	5/11/2000		22.5	1,724	7.9	18.9	230	0.13	1.1	1.0	0.41	<2.5	66	50
PC3	Pigeon Creek	5/8/2000		21.3	1,303	7.74	14.8	172	0.43	1.7	2.0	0.68	<2.5	83	110
PC4	Pigeon Creek	5/13/2000		21.4	1,643	7.97	15	180	0.36	5.0	0.87	0.43	<2.5	65	120
PC4 dup	Pigeon Creek	5/13/2000							0.22	<1.0	0.88	0.42	<2.5	62	70
PC5	Pigeon Creek	5/11/2000		22.8	1,667	7.88	17.3	213	1.8	<1.0	0.78	0.4	<2.5	51	130
PC6	Pigeon Creek	5/13/2000		20.6	1,663	7.89	14.3	168	0.11	<1.0	0.68	0.42	<2.5	200	2000
PC7	Pigeon Creek	5/11/2000		22.3	1,227	7.89	17.2	209	2.0	<1.0	0.96	0.43	<2.5	79	48
PC8	Pigeon Creek	5/3/2000		20.5	1,793	7.8	8.5	100	0.65	3.5	0.52	0.59	<2.5	54	63
PC9	Pigeon Creek	5/10/2000		23.5	1,765	8.01	20.1	254	6.5	1.5	1.1	0.81	3	130	470
PC11	Pigeon Creek	5/10/2000		20.2	1,673	8.12	20.2	235	1.2	<1.0	1.4	0.75	<2.5	160	110
PC12	Pigeon Creek	5/10/2000		22.1	1,149	8.17	18.7	222	2.0	<1.0	1.5	0.7	2.6	86	40
PC13	Pigeon Creek	5/8/2000		23.6	1,640	8.11	18.7	233	0.82	<1.0	2.9	0.64	<2.5	54	100
PC14	Pigeon Creek	5/2/2000		25.3	542	8.46	12.6	153	1.0	<1.0	1.4	0.39	<2.5	9	134
PC15	Pigeon Creek	5/2/2000		24.5	6,309	8.01	10.3	124	0.82	2.7	1.3	0.55	<2.5	4	18
PC16	Pigeon Creek	5/8/2000		23.2	675	8.05	21.1	252	0.11	1.3	1.2	0.5	<2.5	32	230

WATER QUALITY DATA
(Source: STORET, EWSU, this study)

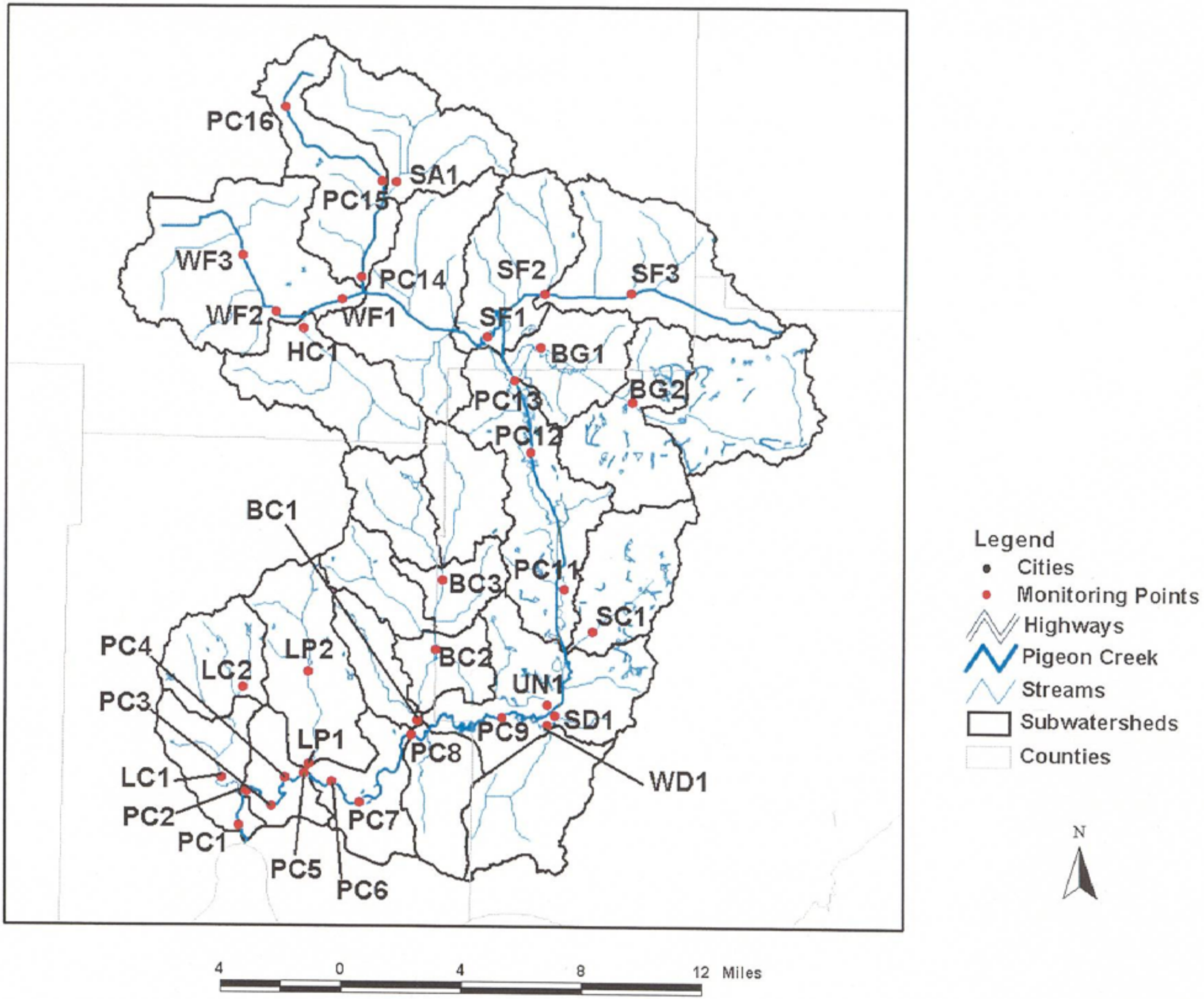
Site	Water body	Date	Time	Temp (C)	Conductivity (umhos)	pH	DO (mg/L)	% DO Saturation	Ammonia N (mg/L)	Total Kjeldahl N (mg/L)	Nitrate N (mg/L)	Phosphorus (mg/L)	BOD (mg/L)	Suspended solids (mg/L)	E. coli (/100 mL)
LC1	Locust Creek	5/6/2000		20.7	418	7.75	14.4	160	0.82	<1.0	0.23	0.07	<2.5	6	190
LC2	Locust Creek	5/6/2000		23	316	7.92	18.5	219	0.28	<1.0	<0.05	0.08	<2.5	22	580
LP1	Little Pigeon Creek	5/6/2000		21	346	7.67	11.7	130	0.37	1.4	0.09	0.18	<2.5	21	480
LP2	Little Pigeon Creek	5/6/2000		21.5	369	7.92	15.5	178	0.51	<1.0	0.13	0.11	<2.5	15	390
BC1	Bluegrass Creek	5/3/2000		21.7	1,488	8	13.8	164	0.22	1.4	0.11	0.45	<2.5	46	86
BC2	Bluegrass Creek	5/3/2000		23.2	1,871	8.5	15.8	170	0.42	<1.0	0.33	0.44	<2.5	29	60
BC3	Bluegrass Creek	5/4/2000		24	548	7.71	14.2	170	1.9	4.2	3.7	0.65	3.9	76	830
BC3 dup	Bluegrass Creek	5/4/2000							1.9	4.2	3.4	0.62	3.6	77	1000
WD1	Weinsheimer Ditch	5/4/2000		20	334	7.6	13.4	146	0.62	1.7	1.4	0.25	4	250	8800
SD1	Stollberg Ditch	5/4/2000		17.5	860	7.37	11.5	122	0.95	10	5.7	2.4	11	34	4500
UN1	Unnamed Tributary	5/4/2000		18.5	1,070	7.58	14	152	0.36	8.4	0.05	0.11	<2.5	36	3000
SC1	Squaw Creek	5/10/2000		17.9	3,295	8.08	23	286	4.9	<1.0	0.11	0.47	<2.5	37	79
BG1	Big Creek	5/7/2000		22.2	2,304	8.1	18.7	232	1.1	1.4	0.43	0.03	<2.5	48	50
BG2	Big Creek	5/7/2000		22.2	2,450	7.99	18.7	234	0.21	1.1	0.16	0.03	<2.5	7	16
SF1	Smith Fork	5/9/2000		22.4	1,672	8.04	17	219	0.16	<1.0	0.14	0.28	<2.5	22	40
SF2	Smith Fork	5/7/2000		22.3	1,693	8.46	24	305	0.78	<1.0	<0.05	0.04	<2.5	3	9
SF3	Smith Fork	5/7/2000		22.5	1,703	8.34	19	232	0.33	1.4	0.12	0.04	<2.5	3	10
SF3 dup	Smith Fork	5/7/2000							0.66	1.4	0.13	0.04	<2.5	4	16
WF1	West Fork	5/1/2000		20.5	572	7.68	15	172	0.46	2.8	8	0.71	3.9	110	7500
WF2	West Fork	5/1/2000		24	636	7.89	15.6	188	2.7	<1.0	8.9	0.23	2.5	70	810
WF3	West Fork	5/1/2000		24	638	8.3	19	230	0.58	<1.0	9.3	0.1	<2.5	21	310
HC1	Hurricane Creek	5/1/2000		25	633	8.02	17.3	212	1.0	2.1	4.9	2.5	3.9	12	2300
SA1	Sand Creek	5/2/2000		27.1	507	8.56	13.2	193	4.3	<1.0	0.66	0.43	<2.5	9	41



HARZA ENGINEERING COMPANY
WATER & ENVIRONMENT

THREATENED AND ENDANGERED SPECIES AND NATURAL AREAS IN THE STUDY AREA
PIGEON CREEK WATERSHED DIAGNOSTIC STUDY

EXHIBIT 8



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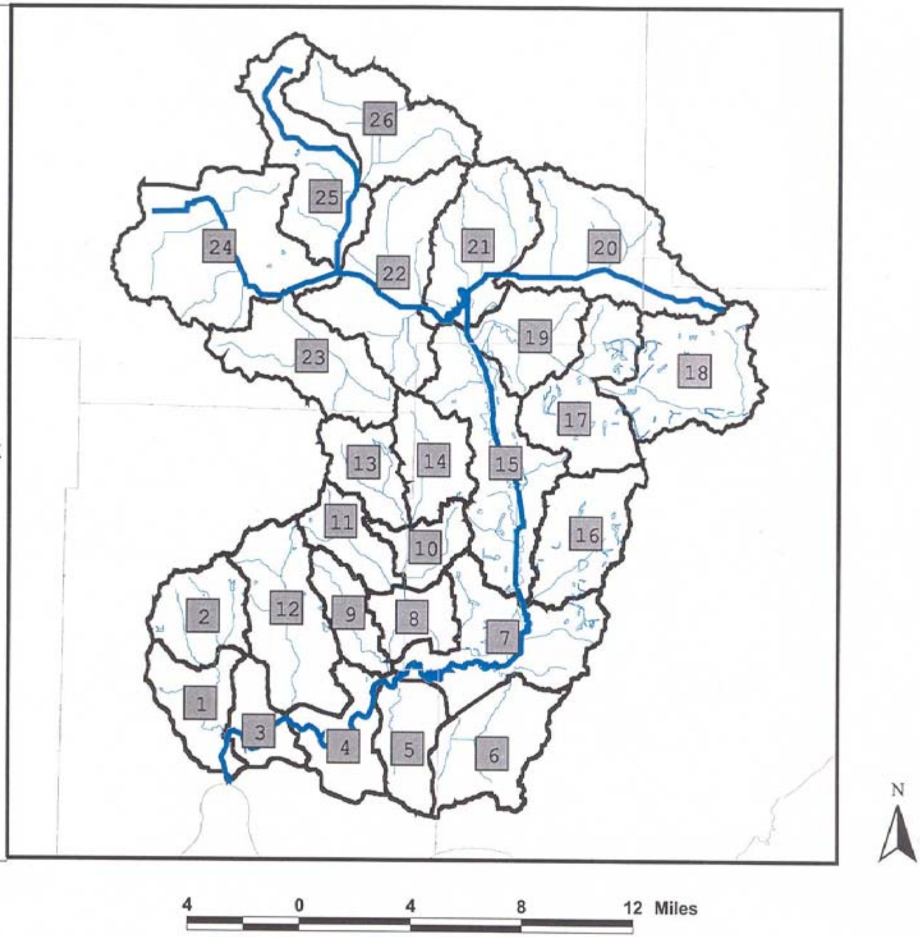
MONITORING SITES
PIGEON CREEK WATERSHED DIAGNOSTIC STUDY

EXHIBIT 9

Subwatersheds

1. Locust Creek Lower
2. Locust Creek Headwaters
3. Kleymeyer Park
4. Harper Ditch
5. Crawford Brandeis Ditch
6. Weinsheimer Ditch
7. Barnes Ditch
8. Dennis Wagner Ditch
9. Firlick Creek
10. Stubbs Fruedenberg Ditch
11. Schlensker Ditch
12. Little Pigeon Creek
13. Unnamed Tributary to Blue Grass Creek
14. Blue Grass Creek Headwaters
15. Clear Branch
16. Squaw Creek
17. Big Creek - Little Creek
18. Big Creek Headwaters
19. Big Creek - Wye
20. Smith Fork Headwaters
21. Smith Fork - Halfmoon Creek
22. Snake Run
23. Hurricane Ditch Creek
24. West Fork Creek
25. Clear Fork Ditch
26. Sand Creek - Muddy Fork Ditch



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SUBWATERSHED BOUNDARIES
PIGEON CREEK WATERSHED DIAGNOSTIC STUDY

EXHIBIT 10

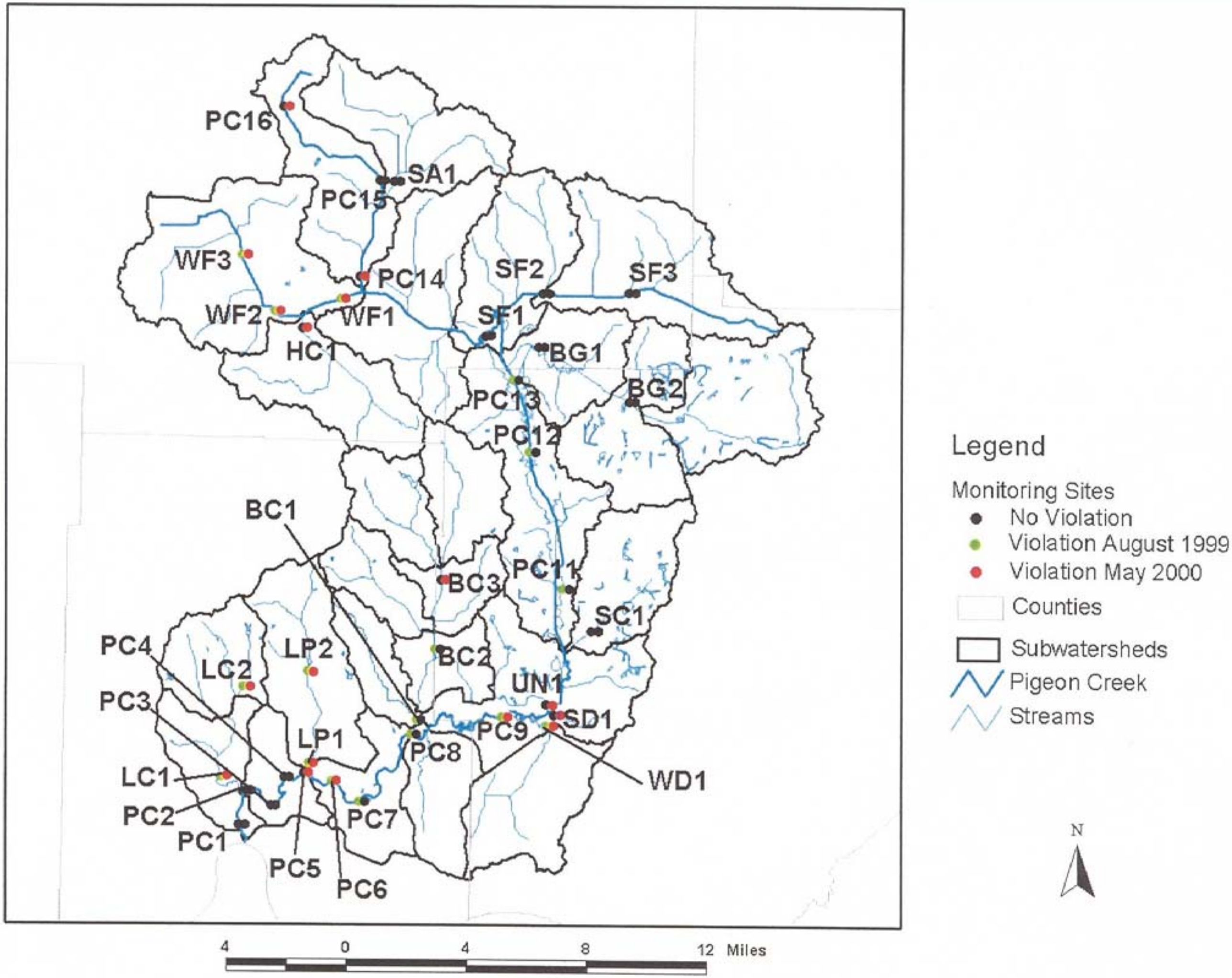
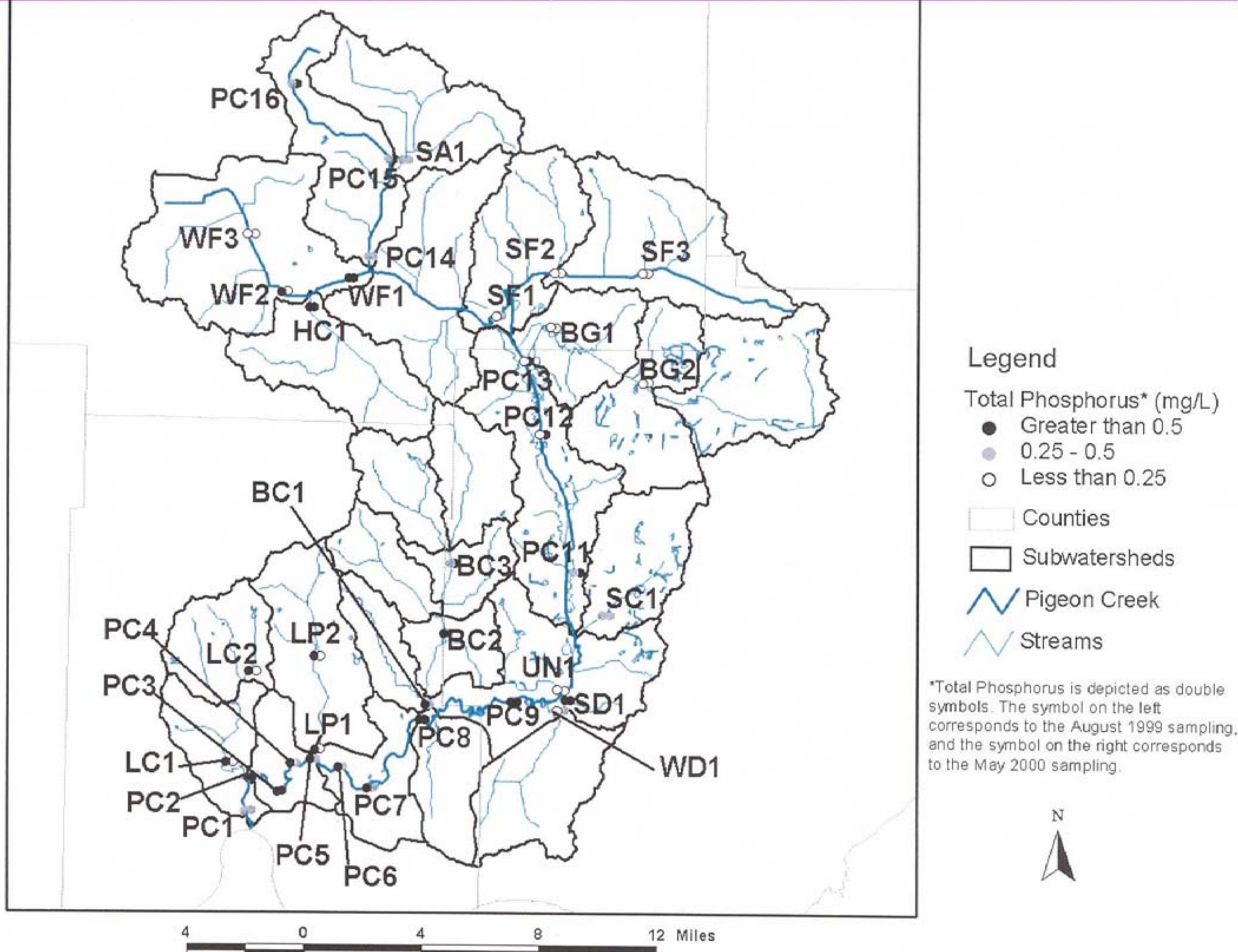


EXHIBIT 11

EXCEEDANCES OF COLIFORM BACTERIA STANDARD AT MONITORING SITES

PIGEON CREEK WATERSHED DIAGNOSTIC STUDY

HARZA ENGINEERING COMPANY
WATER & ENVIRONMENT

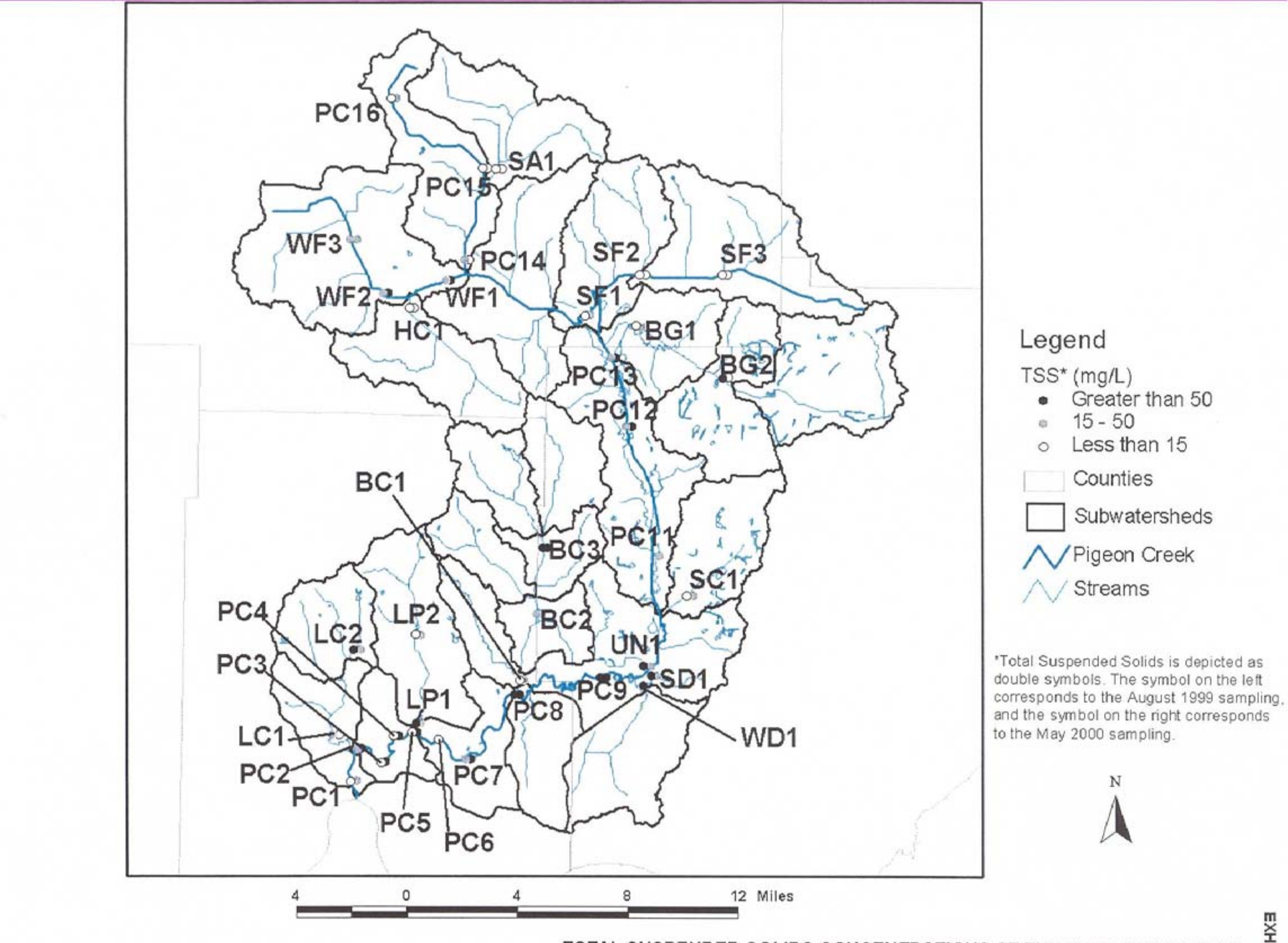


HARZA ENGINEERING COMPANY
WATER & ENVIRONMENT

TOTAL PHOSPHORUS CONCENTRATIONS AT THE MONITORING SITES

PIGEON CREEK WATERSHED DIAGNOSTIC STUDY

EXHIBIT 12

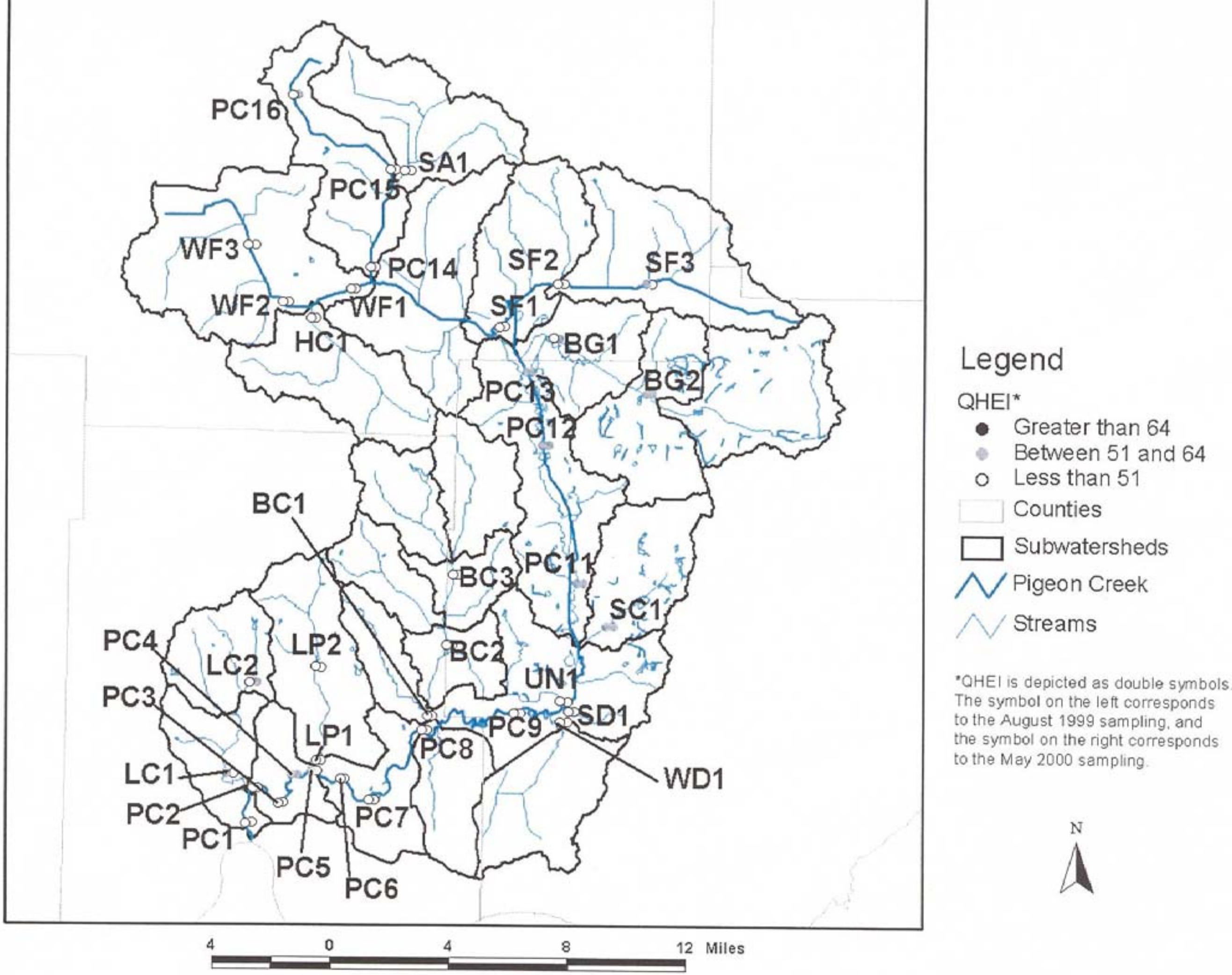


HARZA ENGINEERING COMPANY
WATER & ENVIRONMENT

TOTAL SUSPENDED SOLIDS CONCENTRATIONS AT THE MONITORING SITES

PIGEON CREEK WATERSHED DIAGNOSTIC STUDY

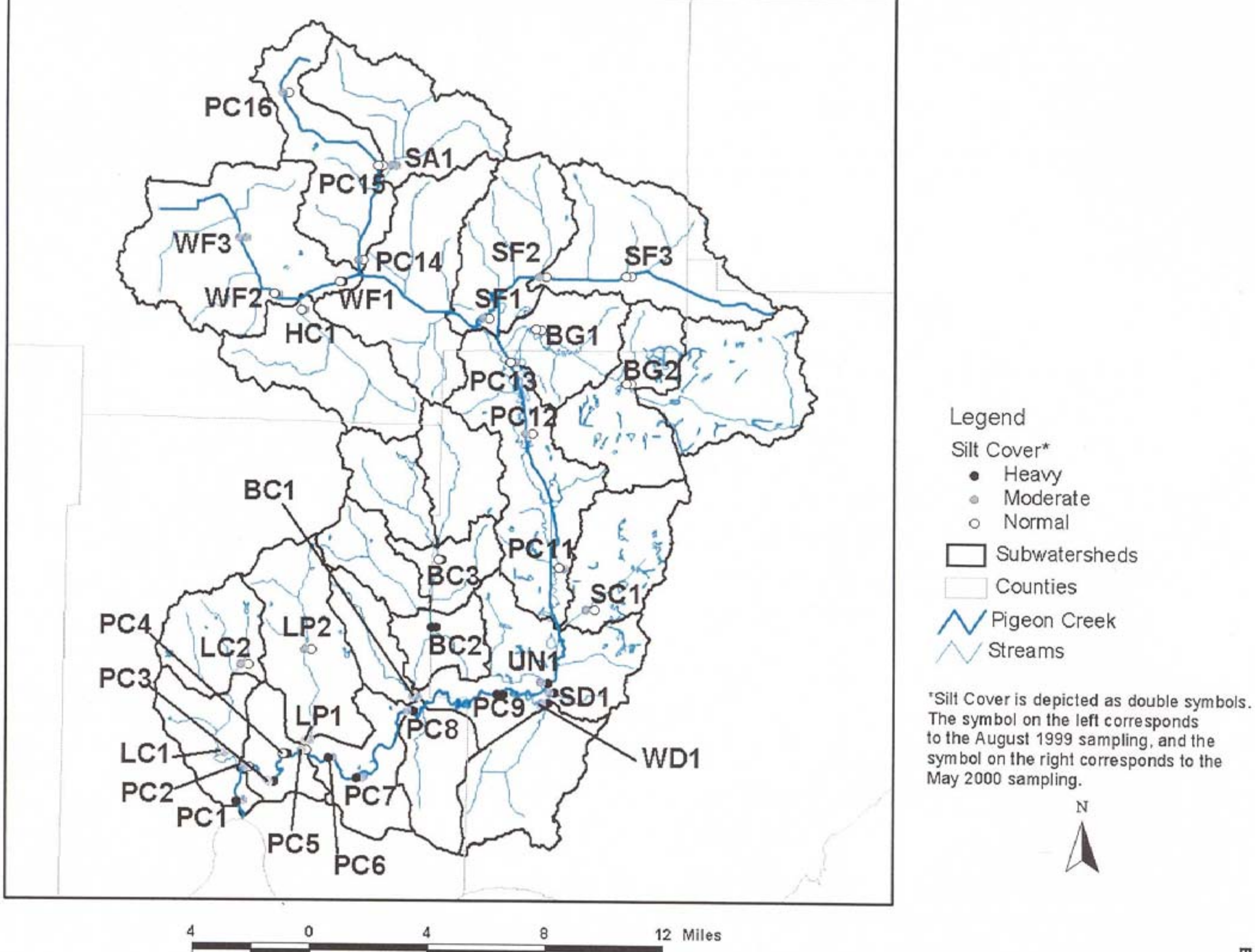
EXHIBIT 13



HARZA ENGINEERING COMPANY
WATER & ENVIRONMENT

QHEI SCORES AT THE MONITORING SITES
PIGEON CREEK WATERSHED DIAGNOSTIC STUDY

EXHIBIT 14

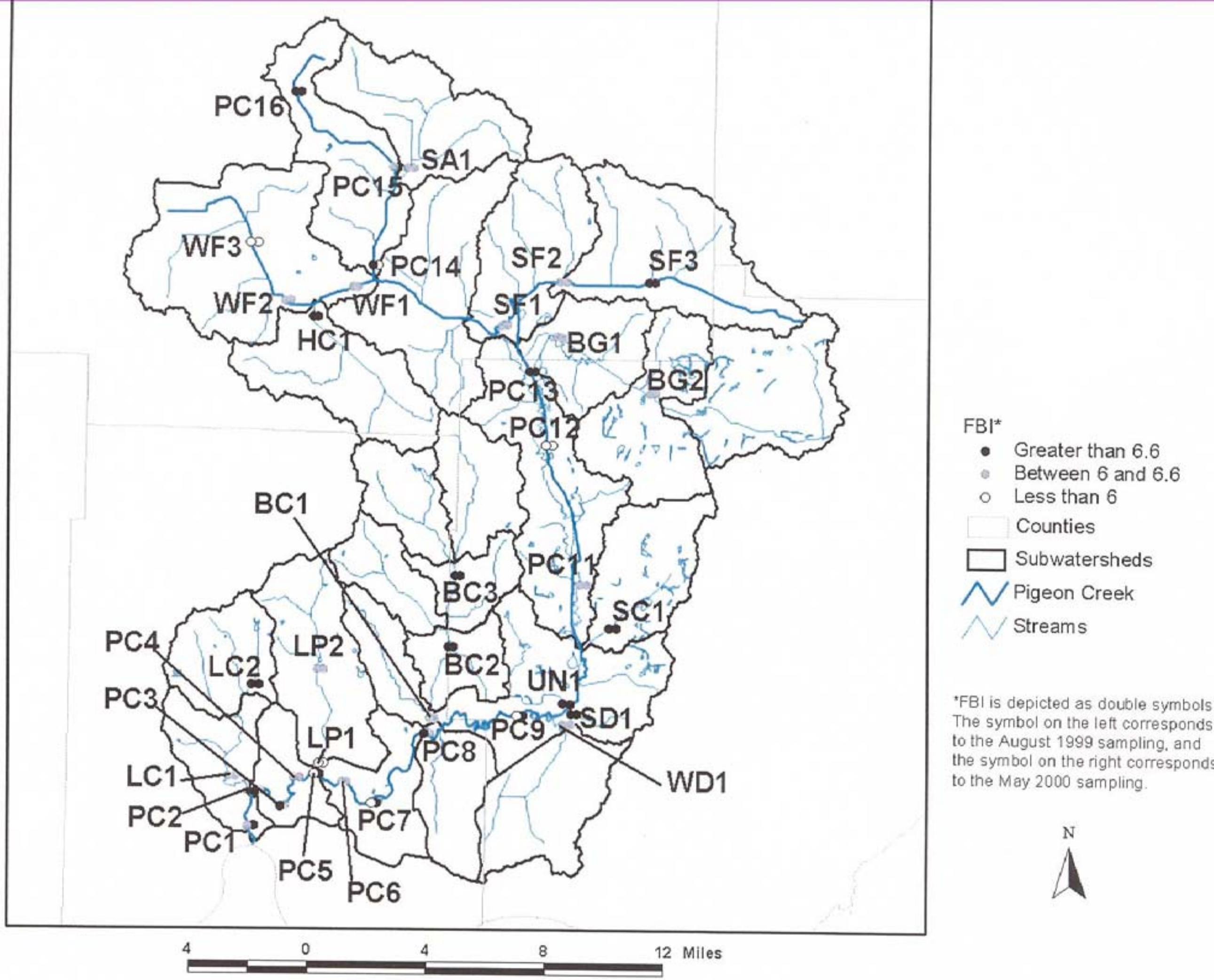


HARZA ENGINEERING COMPANY
WATER & ENVIRONMENT

SILT COVER AT THE MONITORING SITES

PIGEON CREEK WATERSHED DIAGNOSTIC STUDY

EXHIBIT 15

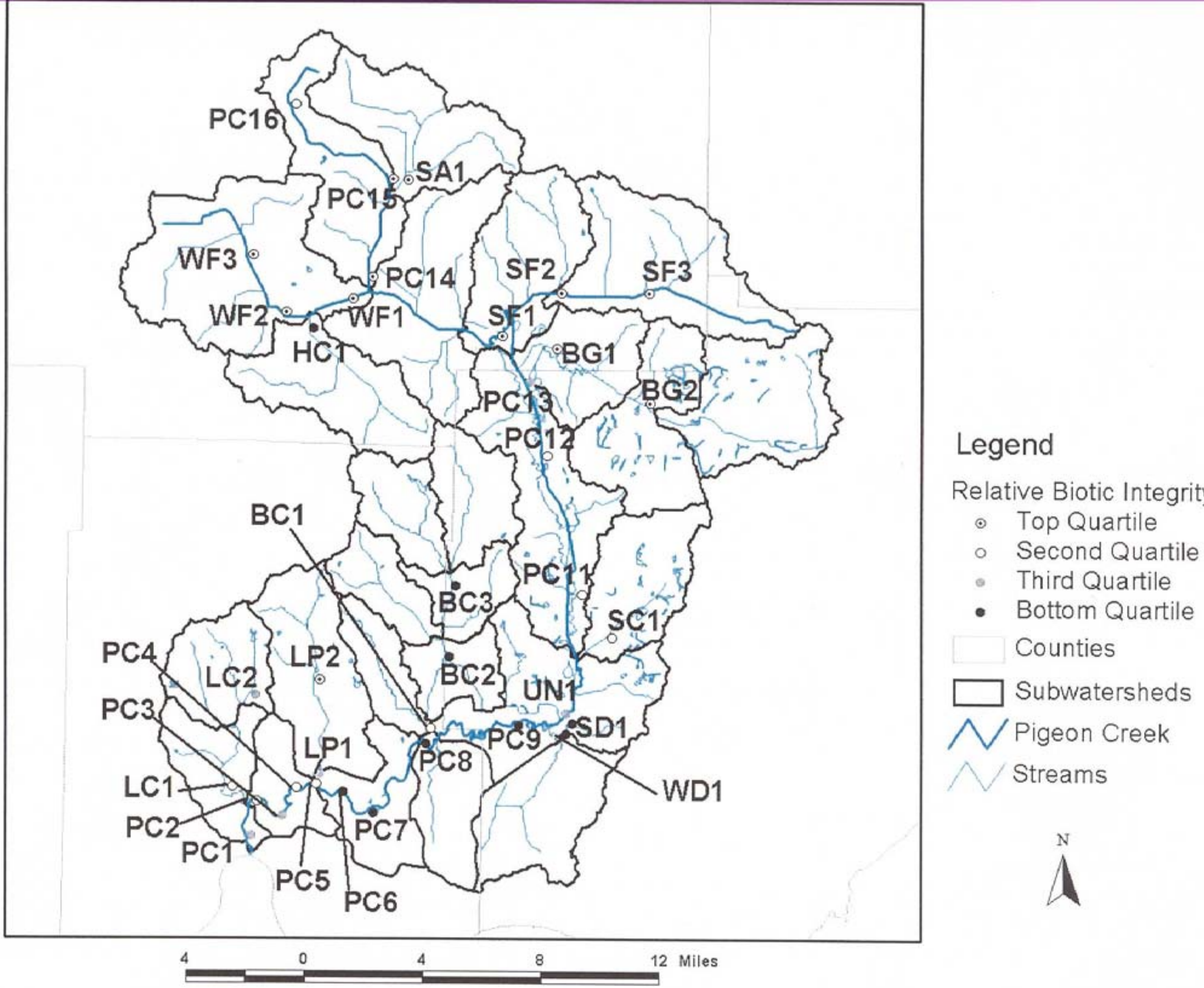


HARZA ENGINEERING COMPANY
WATER & ENVIRONMENT

FAMILY BIOTIC INDICIES AT THE MONITORING SITES

PIGEON CREEK WATERSHED DIAGNOSTIC STUDY

EXHIBIT 16



HARZA ENGINEERING COMPANY
WATER & ENVIRONMENT

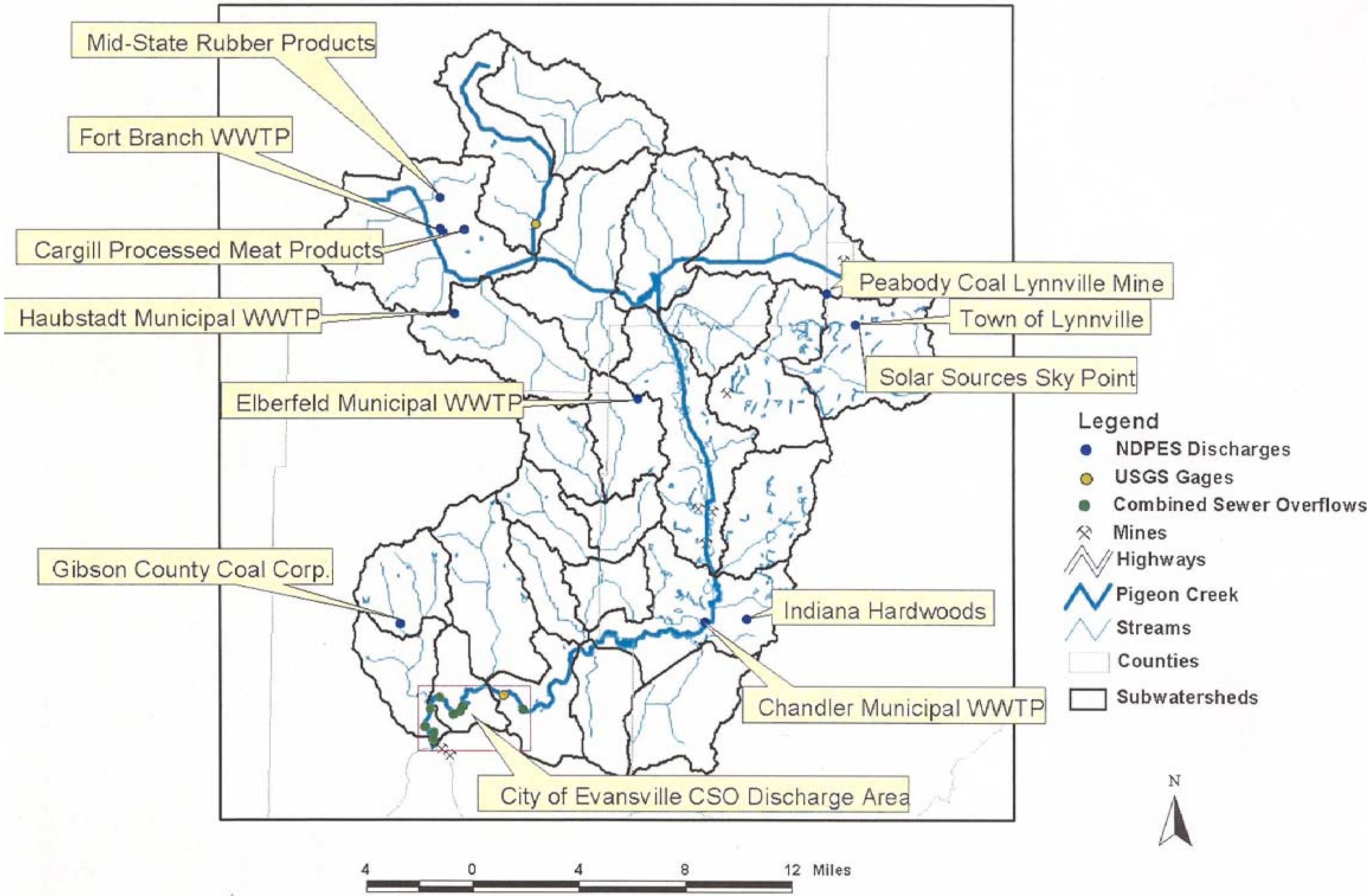
RELATIVE BIOTIC INTEGRITY AT THE MONITORING SITES
PIGEON CREEK WATERSHED DIAGNOSTIC STUDY

EXHIBIT 17

Exhibit 18

RANKING OF MONITORING SITES AND SUBWATERSHEDS BY ECOLOGICAL HEALTH INDICATORS

			Aug-99										May-00															
Monitoring Site	Water Body	Subwatershed	Coliforms		Phosphorus		Suspended Solids		Siltation		FBI		Coliforms		Phosphorus		Suspended Solids		Siltation		FBI		Site			Subwatershed		
			per 100mL	Points	mg/L	Points	mg/L	Points	Rating	Points	Score	Points	per 100mL	Points	mg/L	Points	mg/L	Points	Rating	Points	Score	Points	Total Points	Rank	Quartile	ID	Average Points	Rank
PC1	Pigeon Creek	1	12	1	0.41	3	9	1	Heavy	5	7.6	5	50	1	0.4	3	32	3	Moderate	3	6.8	4	29	22	3	1	28	10
PC2	Pigeon Creek	3	36	1	0.66	4	25	3	Moderate	3	6.3	3	50	1	0.41	3	66	4	Normal	1	6.4	3	26	15	2	3	25.8	8
PC3	Pigeon Creek	3	92	1	0.68	4	13	2	Moderate	3	4.6	1	110	1	0.68	4	83	5	Heavy	5	6.2	3	29	23	3	3	25.8	8
PC4	Pigeon Creek	3	70	1	0.67	4	13	2	Normal	1	4.2	0	95	1	0.425	3	63.5	4	Heavy	5	6.3	3	24	10	2	3	25.8	8
PC5	Pigeon Creek	3	60	1	0.68	4	14	2	Moderate	3	4.3	0	130	2	0.4	3	51	4	Normal	1	6.8	4	24	11	2	3	25.8	8
PC6	Pigeon Creek	4	24,000	5	0.73	4	13	2	Heavy	5	6.7	4	2000	5	0.42	3	200	5	Moderate	3	6.1	3	39	34	4	4	37.5	18
PC7	Pigeon Creek	4	16,000	5	0.7	4	36	3	Heavy	5	5.8	2	48	1	0.43	3	79	5	Moderate	3	7.3	5	36	32	4	4	37.5	18
PC8	Pigeon Creek	5	1,000	5	0.78	4	68	4	Moderate	3	4.9	1	63	1	0.59	4	54	4	Heavy	5	6.6	4	35	29	4	5	35	15
PC9	Pigeon Creek	7	210	2	0.98	5	72	5	Heavy	5	6	2	470	3	0.81	5	130	5	Heavy	5	6.7	4	41	35	4	7	38	18
PC11	Pigeon Creek	15	180	2	0.44	3	34	3	Normal	1	4.8	1	110	1	0.75	4	160	5	Moderate	3	6	3	26	16	2	15	26	9
PC12	Pigeon Creek	15	295	3	0.16	2	23	3	Moderate	3	4.6	1	40	1	0.7	4	86	5	Normal	1	5.3	1	24	12	2	15	26	9
PC13	Pigeon Creek	15	420	3	0.21	3	35	3	Normal	1	5.3	1	100	1	0.64	4	54	4	Moderate	3	7.3	5	28	21	3	15	26	9
PC14	Pigeon Creek	25	8	1	0.48	3	20	2	Moderate	3	5.9	2	134	2	0.39	3	9	1	Normal	1	5.9	2	20	7	1	25	24	7
PC15	Pigeon Creek	25	0	0	0.47	3	8	1	Normal	1	5.2	1	18	1	0.55	4	4	1	Normal	1	7.2	5	18	4	1	25	24	7
PC16	Pigeon Creek	25	0	0	0.4	3	12	2	Moderate	3	7.4	5	230	3	0.5	3	32	3	Normal	1	6.8	4	27	17	2	25	24	7
LC1	Locust Creek	1	880	4	0.59	4	27	3	Moderate	3	6	2	190	3	0.07	1	6	1	Moderate	3	6.1	3	27	18	2	1	28	10
LC2	Locust Creek	2	610	4	0.66	4	140	5	Moderate	3	6.7	4	580	4	0.08	1	22	3	Normal	1	6.7	4	33	26	3	2	33	13
LP1	Little Pigeon Ck	12	1,100	5	0.6	4	51	4	Moderate	3	5.9	2	480	3	0.18	2	21	3	Moderate	3	5.9	2	31	25	3	12	31	6
LP2	Little Pigeon Ck	12	320	3	0.59	4	9	1	Moderate	3	5.1	1	390	3	0.11	2	15	2	Normal	1	6.4	3	23	9	1	12	23	6
BC1	Bluegrass Creek	9	3,500	5	0.56	4	5	1	Moderate	3	5.6	2	86	1	0.45	3	46	4	Moderate	3	6.6	4	30	24	2	9	30	11
BC2	Bluegrass Creek	8	540	4	0.55	4	19	2	Heavy	5	8.2	5	60	1	0.44	3	29	3	Heavy	5	6.9	5	37	33	4	8	37	17
BC3	Bluegrass Creek	10	27	1	0.29	3	51	4	Normal	1	6.4	3	915	4	0.635	4	76.5	5	Heavy	5	7	5	35	30	4	10	35	15
WD1	Weinsheimer Dit	7	200	2	0.12	2	69	4	Moderate	3	6	2	8800	5	0.25	3	250	5	Heavy	5	6.6	4	35	31	4	7	37.5	18
SD1	Stollberg Ditch	7	70	1	2.9	5	70	4	Moderate	3	7.7	5	4500	5	2.4	5	34	3	Heavy	5	7.9	5	41	36	4	7	37.5	18
UN1	Unnamed Trib	7	43	1	0.08	1	61	4	Moderate	3	6.7	4	3000	5	0.11	2	36	3	Heavy	5	7	5	33	27	3	7	37.5	18
SC1	Squaw Creek	16	67	1	0.3	3	8	1	Moderate	3	6.3	3	79	1	0.47	3	37	3	Normal	1	7	5	24	13	2	16	24	7
BG1	Big Creek	19	98	1	0.05	1	11	2	Normal	1	5.8	2	50	1	0.03	1	48	4	Normal	1	6	2	16	2	1	19	16	2
BG2	Big Creek	18	10	1	0.02	0	60	4	Normal	1	6.4	3	16	1	0.03	1	7	1	Normal	1	6.2	3	16	3	1	18	16	2
SF1	Smith Fork	21	110	1	0.07	1	5	1	Moderate	3	5.6	2	40	1	0.28	3	22	3	Normal	1	6	2	18	5	1	21	18	4
SF2	Smith Fork	20	25	1	0.07	1	10	1	Moderate	3	7	5	9	1	0.04	1	3	1	Normal	1	6.4	3	18	6	1	20	16	1
SF3	Smith Fork	20	54	1	0.09	1	2	0	Normal	1	5.4	1	10	1	0.04	1	3	1	Normal	1	7.5	5	13	1	1	20	15.5	1
WF1	West Fork	25	230	2	1.4	5	24	3	Normal	1	6.1	3	13	1	0.04	1	3.5	1	Heavy	5	6.2	3	25	14	2	25	24	7
WF2	West Fork	25	540	4	0.6	1	20	2	Normal	1	5.4	1	810	4	0.23	3	70	4	Moderate	3	6.5	4	27	19	3	25	24	7
WF3	West Fork	25	270	3	0.06	1	22	3	Moderate	3	7.8	5	310	3	0.1	1	21	3	Moderate	3	5.6	2	27	20	3	25	24	7
HC1	Hurricane Creek	23	39	1	7.2	5	14	2	Normal	1	6.7	4	2300	5	2.5	5	12	2	Moderate	3	7.2	5	33	28	4	23	33	14
SA1	Sand Creek	26	5	1	0.43	3	10	1	Moderate	3	6.4	3	41	1	0.43	3	9	1	Moderate	3	6.3	3	22	8	1	26	22	5



HARZA ENGINEERING COMPANY
WATER & ENVIRONMENT

POLLUTANT POINT SOURCES

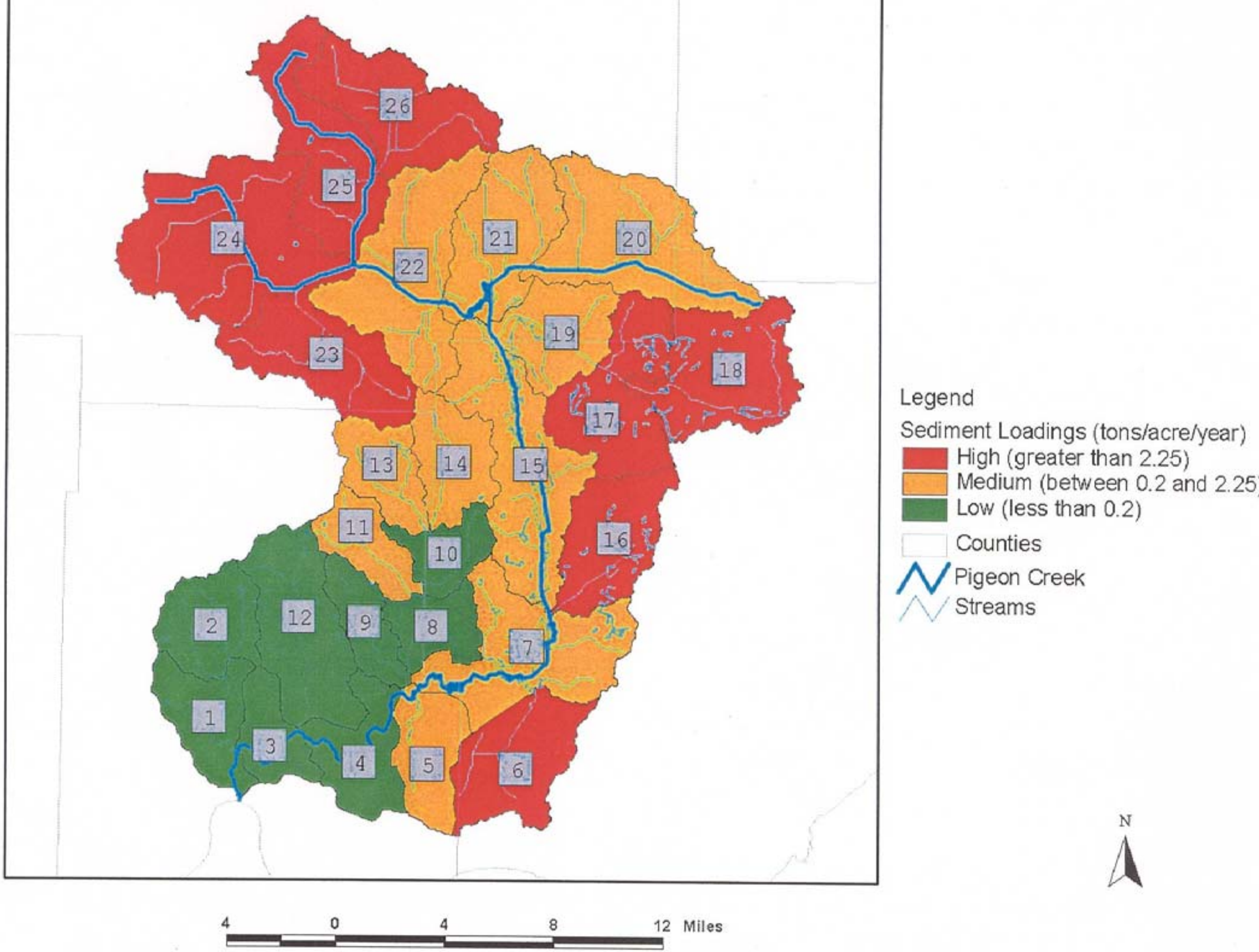
PIGEON CREEK WATERSHED DIAGNOSTIC STUDY

EXHIBIT 19

Exhibit 20

NPDES PERMITTED FACILITIES IN THE PIGEON CREEK WATERSHED
(Source: USEPA Permit Compliance System)

FACILITY	CITY	COUNTY	SIC	RECEIVING WATER	FLOW (MGD)	NPDES
Indiana Hardwoods, Kimball Intern'l	Chandler	Warrick	2435	Pigeon Cr via Strollberg D via D.		IN0058530
Ashland Oil Co. Evansville Evansville	Evansville	Vanderburgh	4226	Ohio River		IN0025348
Evansville Materials	Evansville	Vanderburgh	1442	Ohio River		IN0001091
Sigeco, Ohio River Station Evansville	Evansville	Vanderburgh	4911	Ohio River		IN0002241
Evansville Water and Sewer Westside Plant	Evansville	Vanderburgh	4952	Ohio River (except certain CSOs)	20.6	IN0032956
Evansville Waterworks Dept	Evansville	Vanderburgh	4941	Ohio River	1.75	IN0043117
Evansville Water and Sewer Eastside	Evansville	Vanderburgh	4952	Ohio River (except certain CSOs)	18.0	IN0033073
Chandler Municipal WWTP	Chandler	Warrick	4952	Pigeon Cr via Strollberg Ditch	0.70	IN0020435
Chandler Water Works	Chandler	Warrick	4941	Ohio River	0.029	IN0004073
Haubstadt Municipal WWTP	Haubstadt	Gibson	4952	Pigeon Cr via Haubstadt Ditch	0.30	IN0021482
Solar Sources Inc. - Pit 12	Lynnville	Warrick	1221	Smith Fork Cr Honey Cr Rough Cr.		IN0047970
Darmstadt Municipal WWTP	Evansville	Vanderburgh	4952	Pigeon Cr via Little Pigeon Creek		IN0052990
Lynnville Municipal WWTP	Lynnville	Warrick	4952	Pigeon Cr via Big Cr via Mill Creek	0.08	IN0040282
Elberfeld Municipal WWTP	Elberfeld	Warrick	4952	Pigeon Cr via Bluegrass Creek	0.3	IN0020788
Warrick Cnty Coal-Lynnville	Elberfeld	Warrick	1221	Pigeon Cr via Big Cr via Plum B - Tr		IN0047287
Cargill Processed Meat Products	Fort Branch	Gibson	2011	Pigeon Cr (W Fk) via Toops Ditch	0.272	IN0001686
Fort Branch Municipal WWTP	Fort Branch	Gibson	4952	Pigeon Cr (W Fk) to Ohio River	0.655	IN0022896

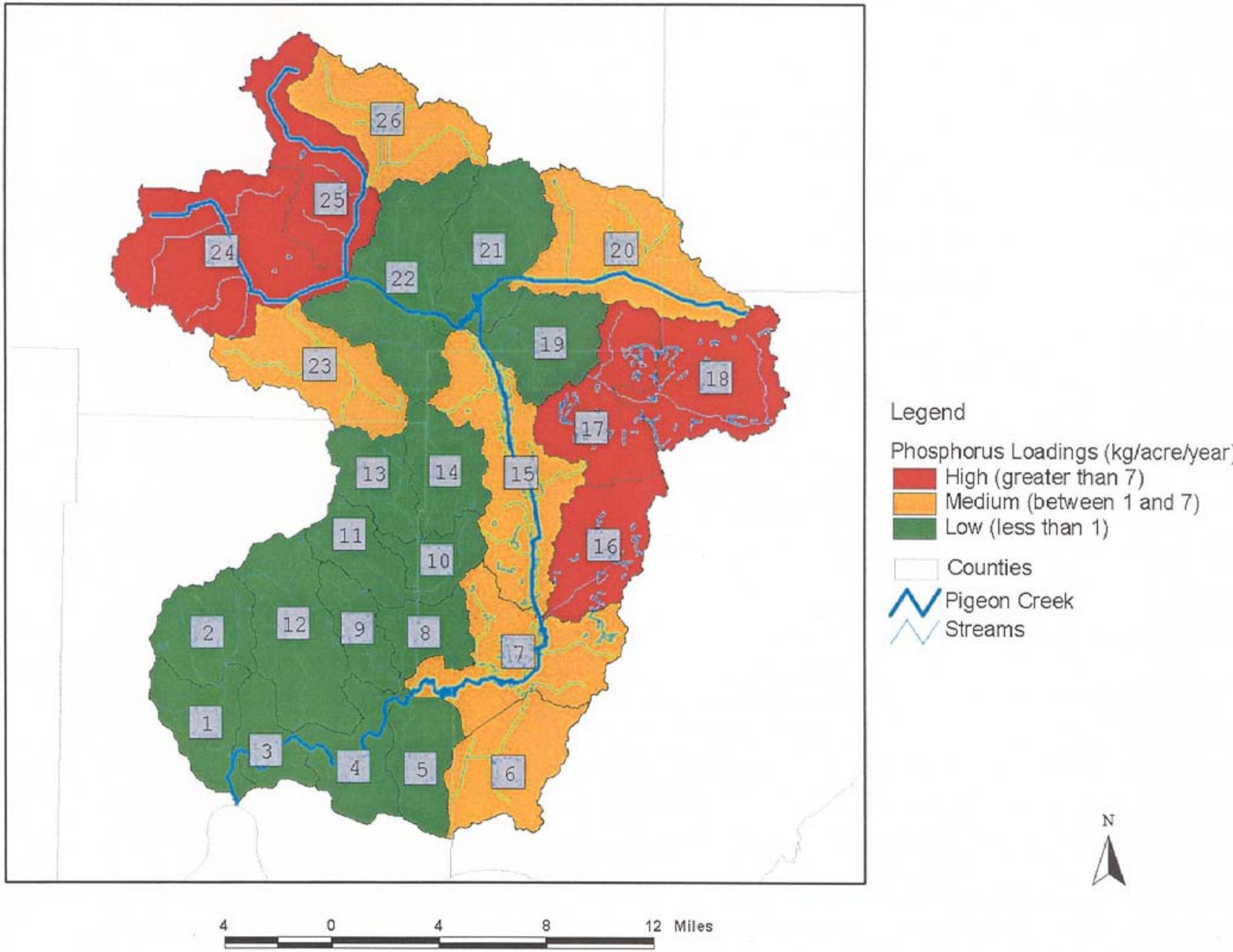


HARZA ENGINEERING COMPANY
WATER & ENVIRONMENT

SEDIMENT LOADINGS TO PIGEON CREEK

PIGEON CREEK WATERSHED DIAGNOSTIC STUDY

EXHIBIT 21



HARZA ENGINEERING COMPANY
WATER & ENVIRONMENT

PHOSPHORUS LOADINGS TO PIGEON CREEK
PIGEON CREEK WATERSHED DIAGNOSTIC STUDY

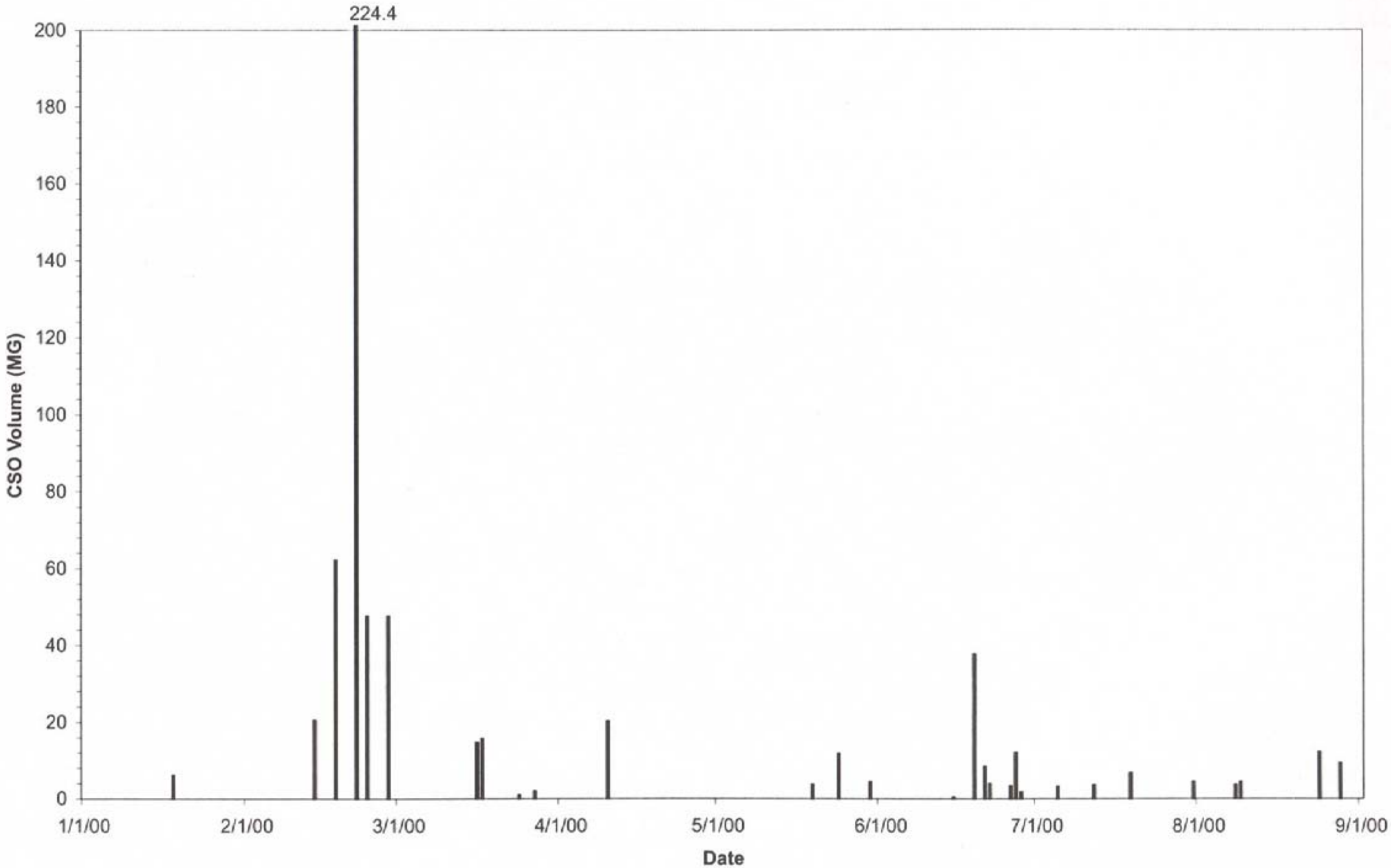
EXHIBIT 22

Exhibit 23

CHARACTERISTICS OF COMBINED SEWER OUTFALLS DISCHARGED TO PIGEON CREEK

(Source: Rust 1997)

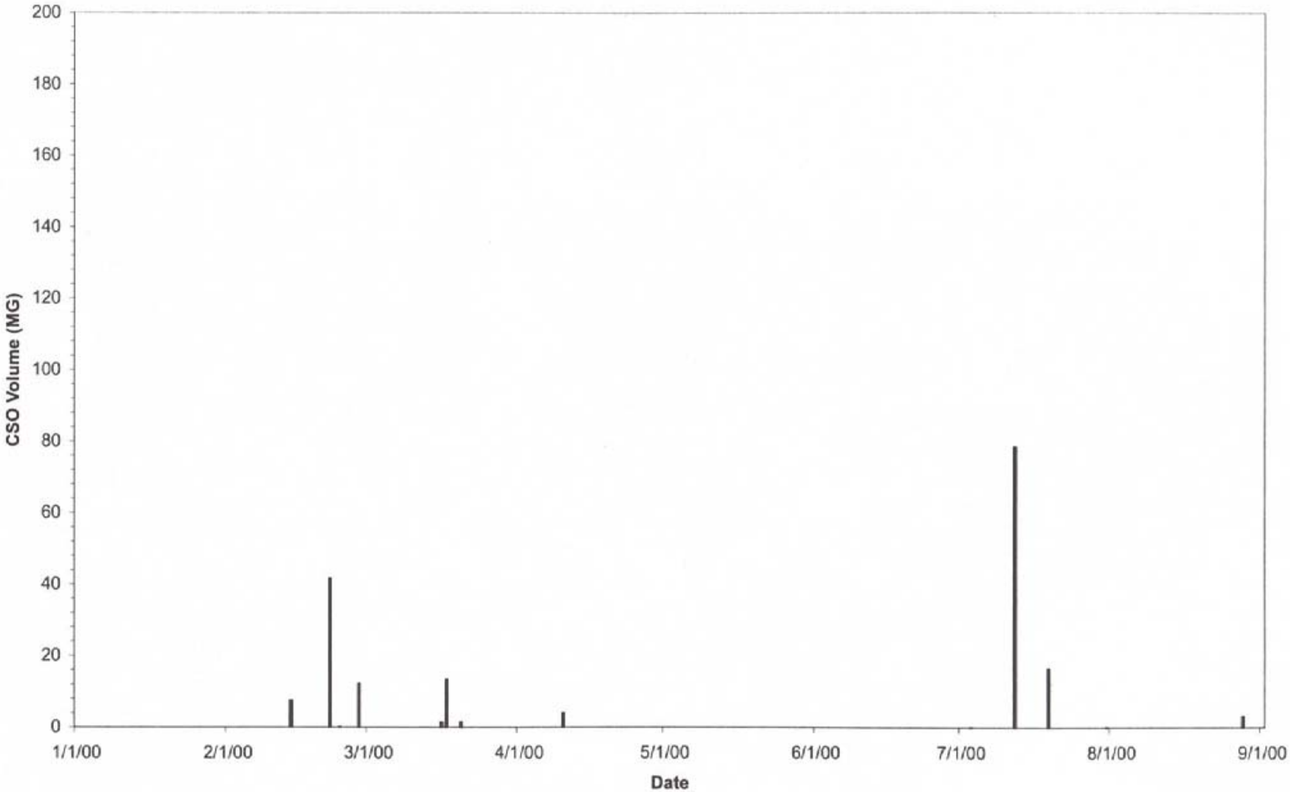
Outfall No.	Name	2-yr 2-hr Storm Discharge (MGD)	Rel Residential Development	Rel Industrial Development	HazChem Spill Probability	Soil Erosion	Overall Floatables/ Solids Rating
011	Oakhill/Weinbach	80.3	High	Moderate	High	High	High
012	Maryland	96.2	Moderate	Moderate	Low	Low	High
013	Delaware	112.2	Moderate	Moderate	High	Low	High
014	Dresden	83.7	Low	High	Moderate	Low	High
016	Franklin	27.3	Moderate	Moderate	Low	Low	Moderate
017	Sixth Avenue	21.6	Moderate	Low	Moderate	Low	Moderate
018	Oakley	23.8	Low	Moderate	Moderate	Low	High
024	Baker	160.1	High	Moderate	Moderate	Low	High
025	Diamond	594.8	Moderate	High	High	High	High



COMBINED SEWER OVERFLOW (Million Gallons) AT DIAMOND
PIGEON CREEK WATERSHED DIAGNOSTIC STUDY
EVANSVILLE WATER AND SEWER UTILITY AND FOUR RIVERS
RESOURCE CONSERVATION AND DEVELOPMENT AREA, INC.
Pigeon Creek, Indiana

EXHIBIT 24

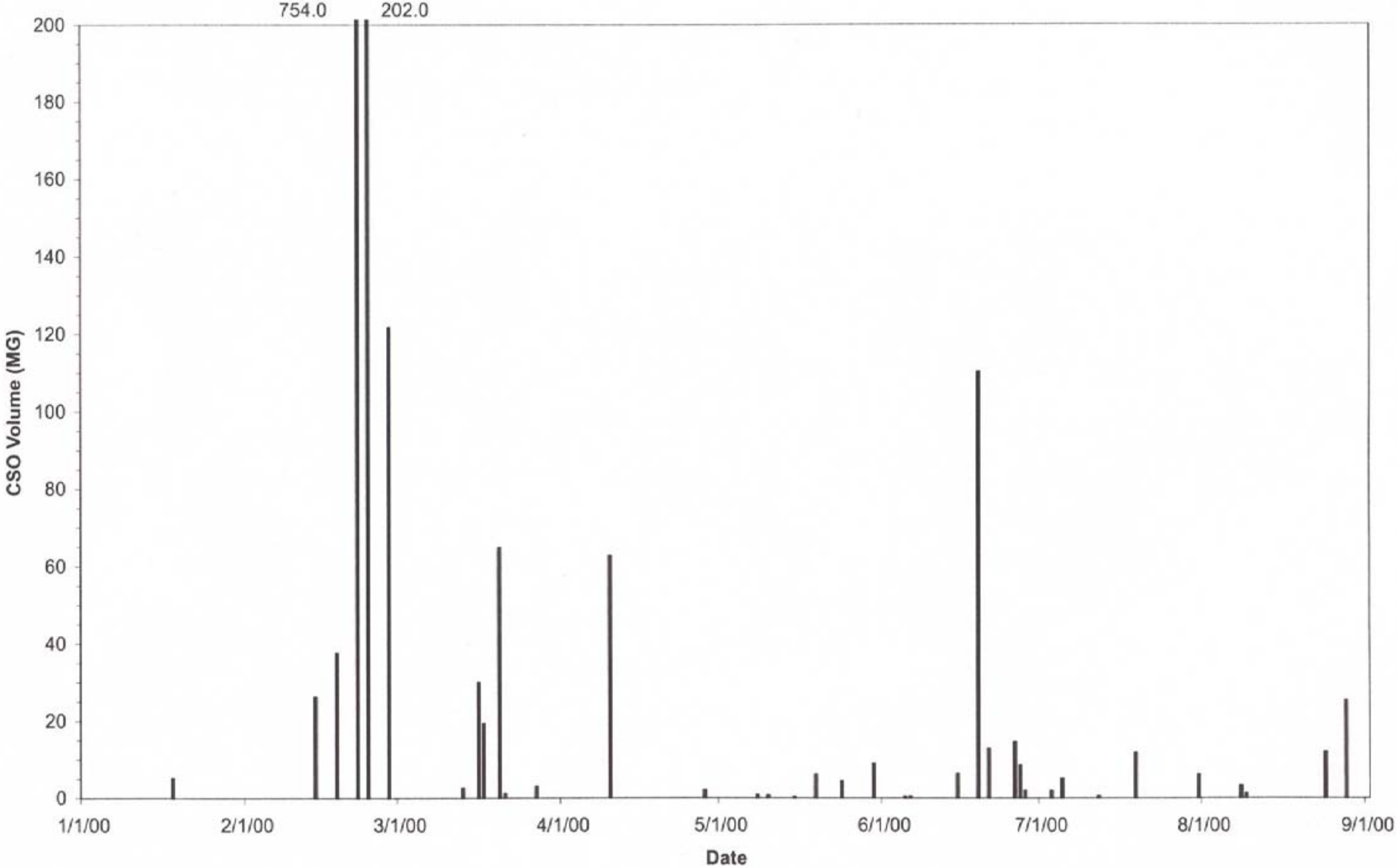
HARZA **ENGINEERING COMPANY**
WATER & ENVIRONMENT



COMBINED SEWER OVERFLOW (Million Gallons) AT OAKHILL
PIGEON CREEK WATERSHED DIAGNOSTIC STUDY
EVANSVILLE WATER AND SEWER UTILITY AND FOUR RIVERS
RESOURCE CONSERVATION AND DEVELOPMENT AREA, INC.
Pigeon Creek, Indiana

EXHIBIT 25

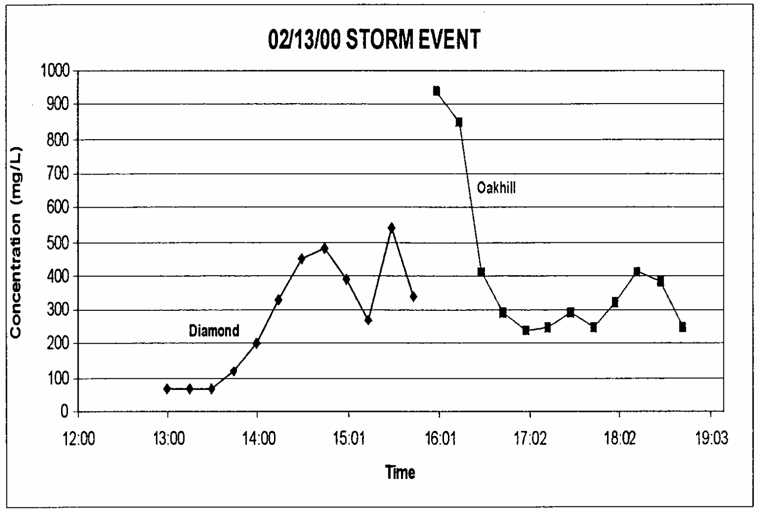
HARZA **ENGINEERING COMPANY**
WATER & ENVIRONMENT

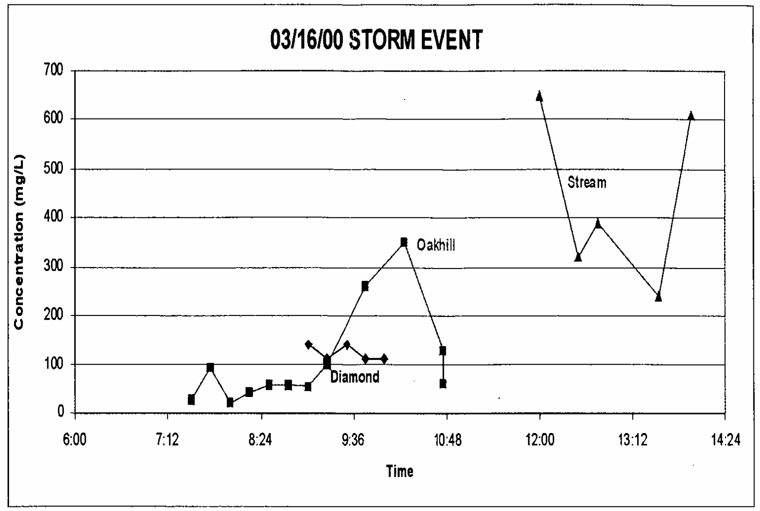


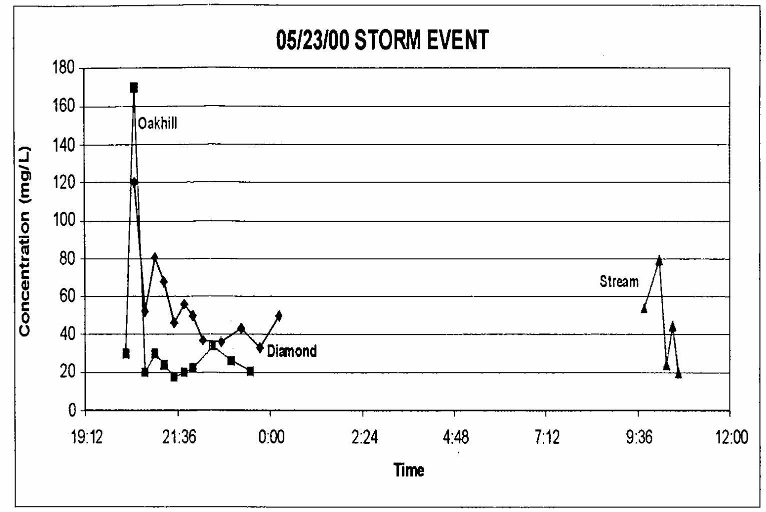
COMBINED SEWER OVERFLOW (Million Gallons) AT MARYLAND
PIGEON CREEK WATERSHED DIAGNOSTIC STUDY
EVANSVILLE WATER AND SEWER UTILITY AND FOUR RIVERS
RESOURCE CONSERVATION AND DEVELOPMENT AREA, INC.
Pigeon Creek, Indiana

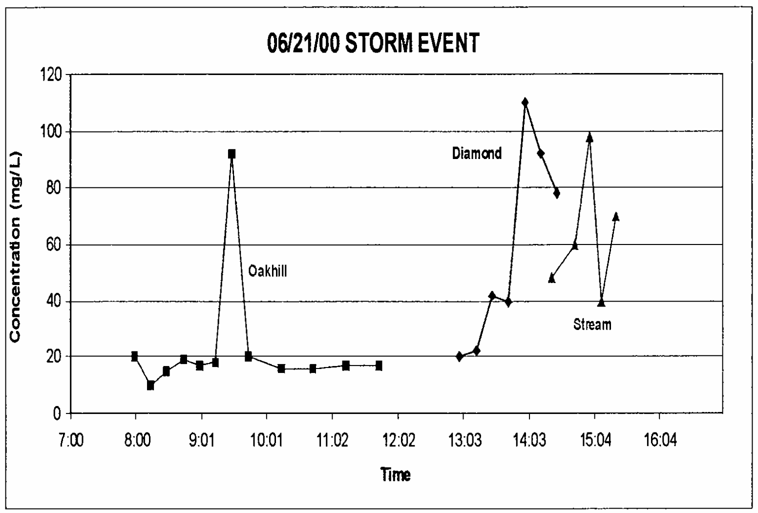
EXHIBIT 26

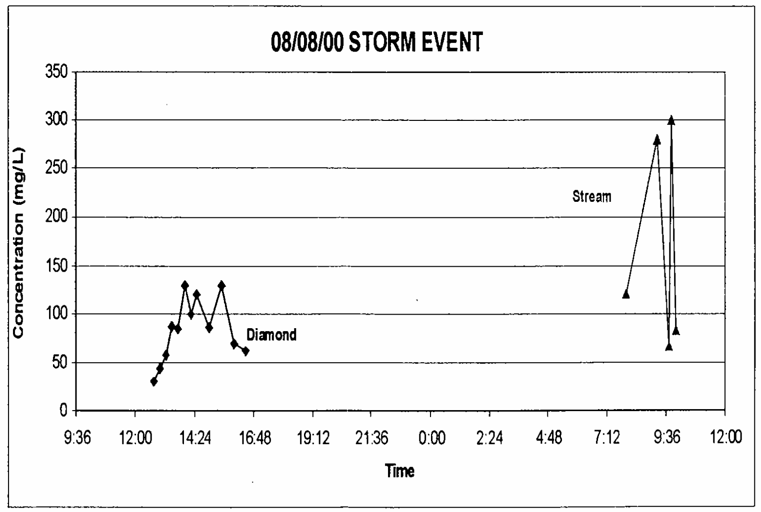
HARZA **ENGINEERING COMPANY**
WATER & ENVIRONMENT

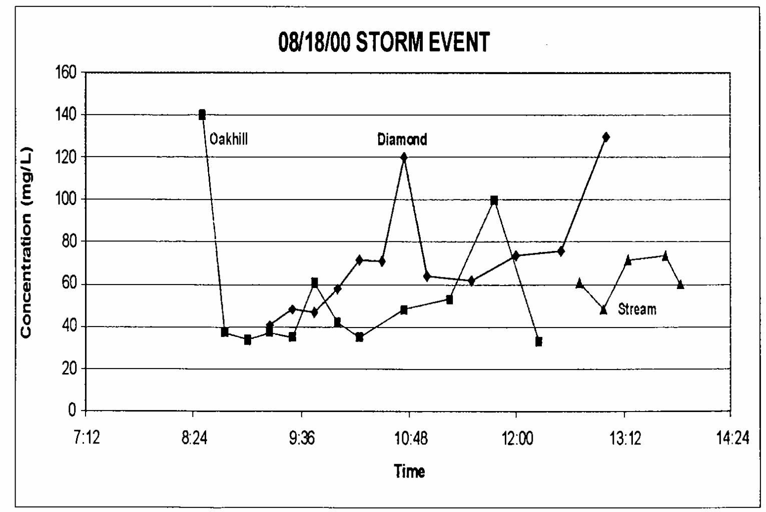












SUSPENDED SOLIDS CONCENTRATIONS FOR ALL STORM EVENTS
PIGEON CREEK WATERSHED DIAGNOSTIC STUDY
EVANSVILLE WATER AND SEWER UTILITY AND
FOUR RIVERS RESOURCE CONSERVATION AND DEVELOPMENT AREA, INC.
Pigeon Creek, Indiana

HARZA ENGINEERING COMPANY
WATER & ENVIRONMENT

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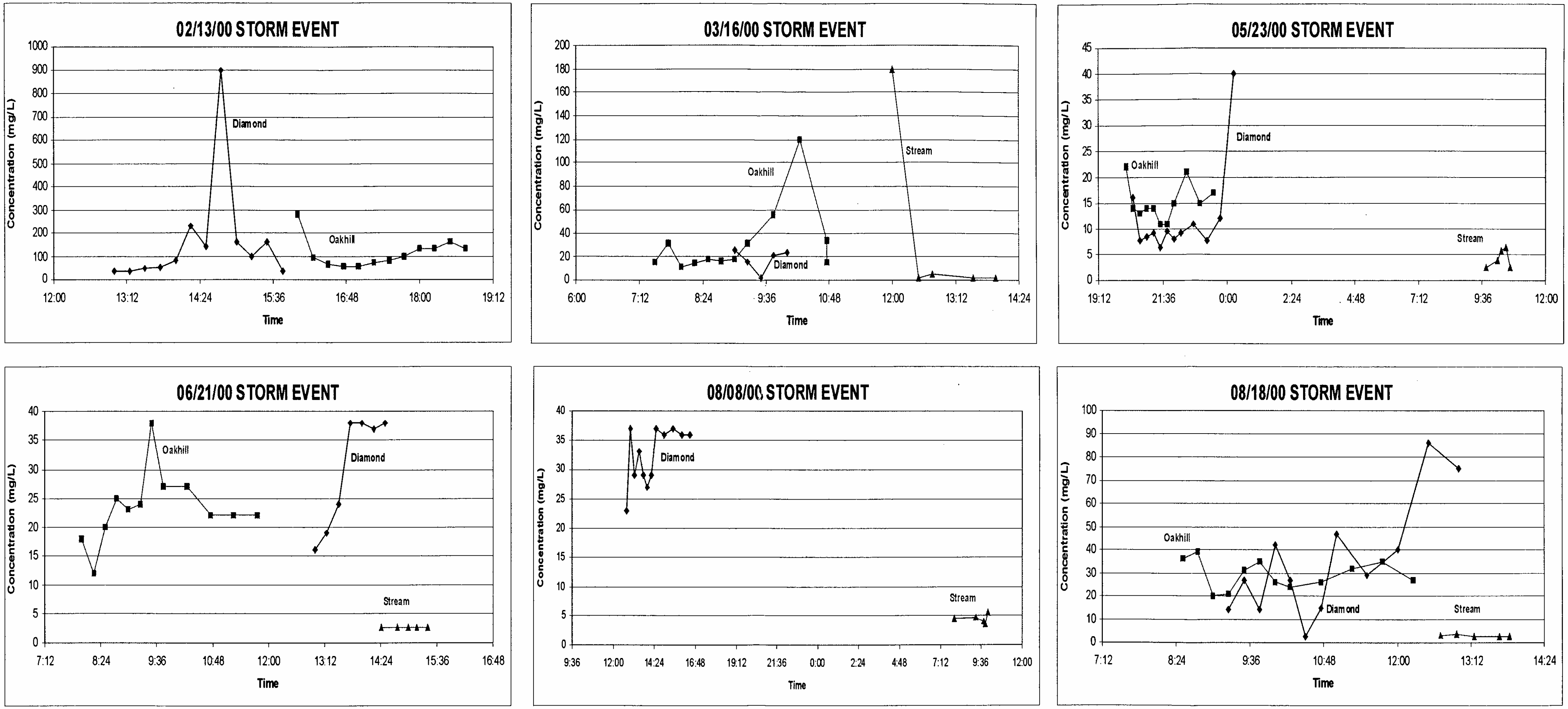

BOD CONCENTRATIONS FOR ALL STORM EVENTS
PIGEON CREEK WATERSHED DIAGNOSTIC STUDY
EVANSVILLE WATER AND SEWER UTILITY AND
FOUR RIVERS RESOURCE CONSERVATION AND DEVELOPMENT AREA, INC.
Pigeon Creek, Indiana

HARZA ENGINEERING COMPANY
WATER & ENVIRONMENT

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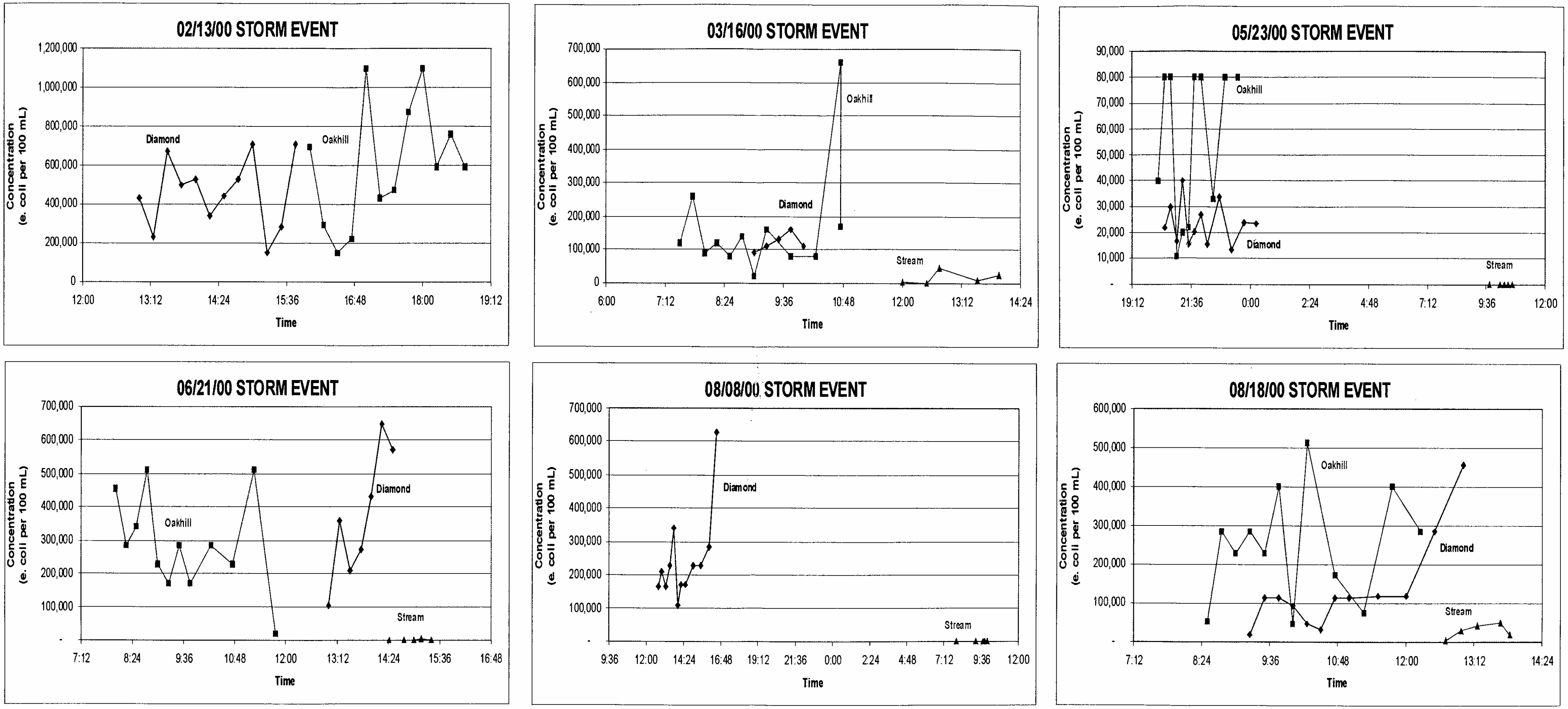
EXHIBIT 29



E.COLI CONCENTRATIONS FOR ALL STORM EVENTS
PIGEON CREEK WATERSHED DIAGNOSTIC STUDY
EVANSVILLE WATER AND SEWER UTILITY AND
FOUR RIVERS RESOURCE CONSERVATION AND DEVELOPMENT AREA, INC.
Pigeon Creek, Indiana

HARZA ENGINEERING COMPANY
WATER & ENVIRONMENT

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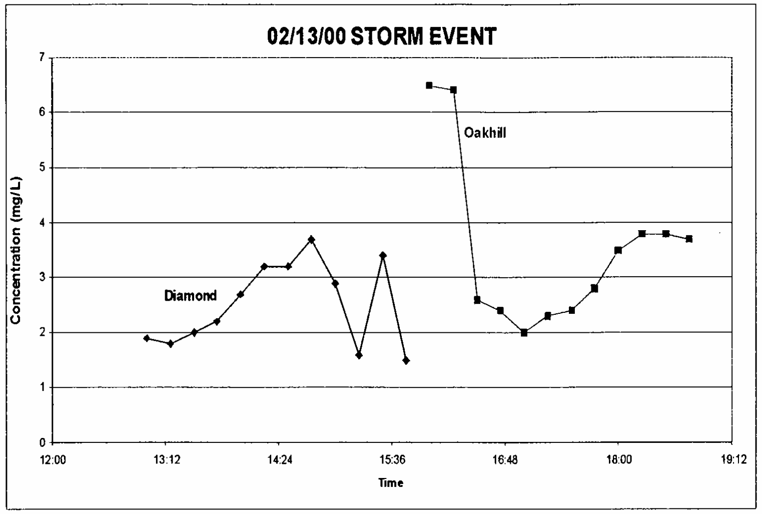
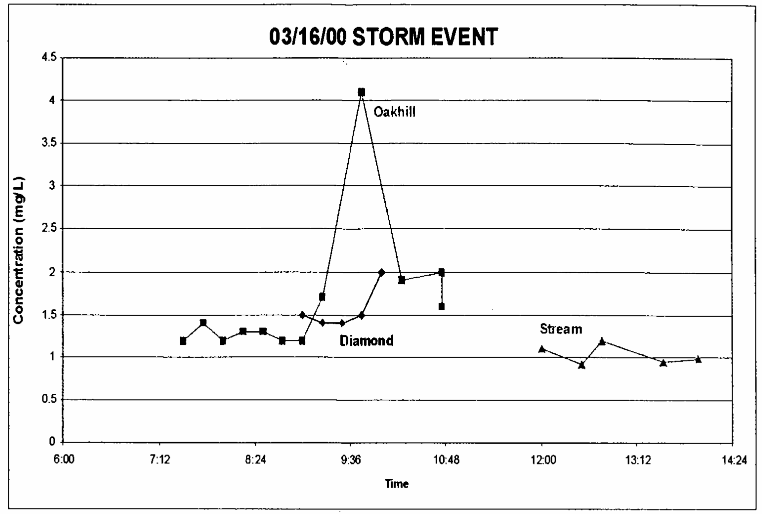
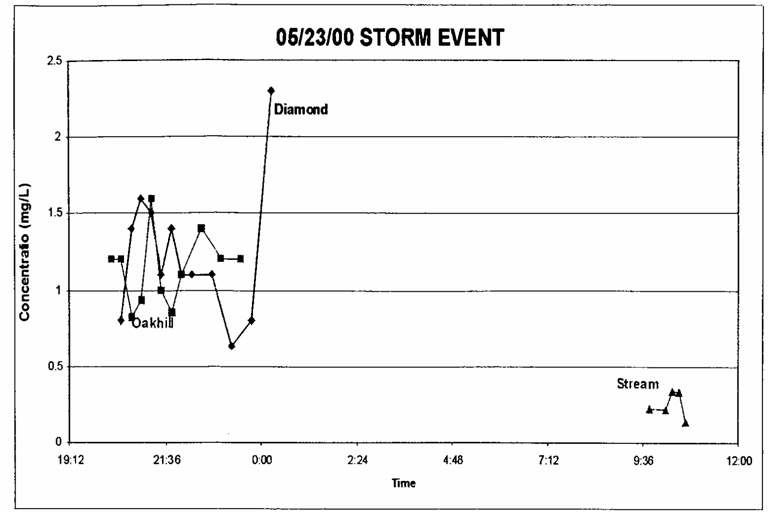
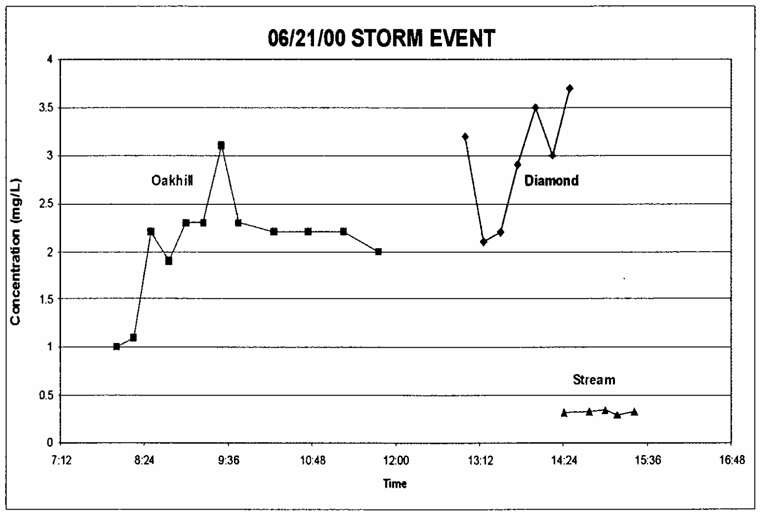
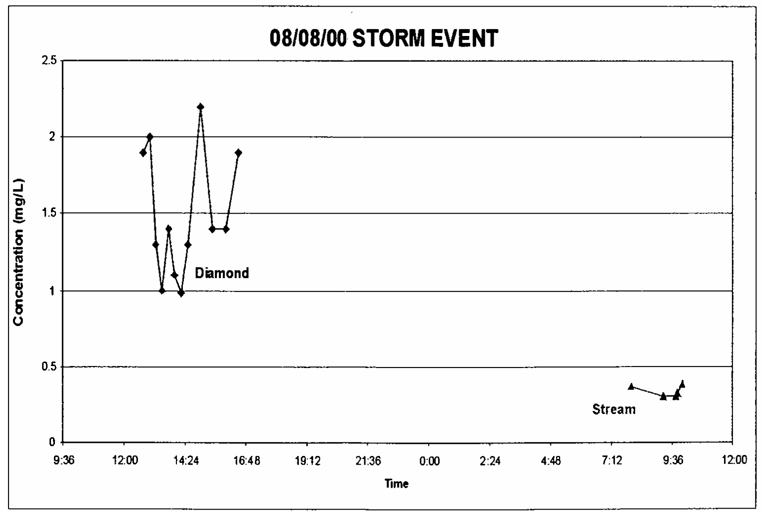
EXHIBIT 30

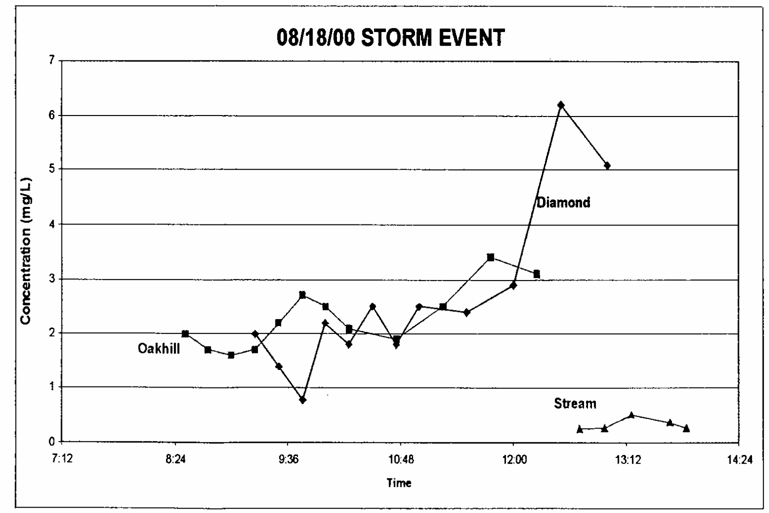












PHOSPHOROUS CONCENTRATIONS FOR ALL STORM EVENTS
PIGEON CREEK WATERSHED DIAGNOSTIC STUDY
EVANSVILLE WATER AND SEWER UTILITY AND
FOUR RIVERS RESOURCE CONSERVATION AND DEVELOPMENT AREA, INC.
Pigeon Creek, Indiana

HARZA ENGINEERING COMPANY
WATER & ENVIRONMENT

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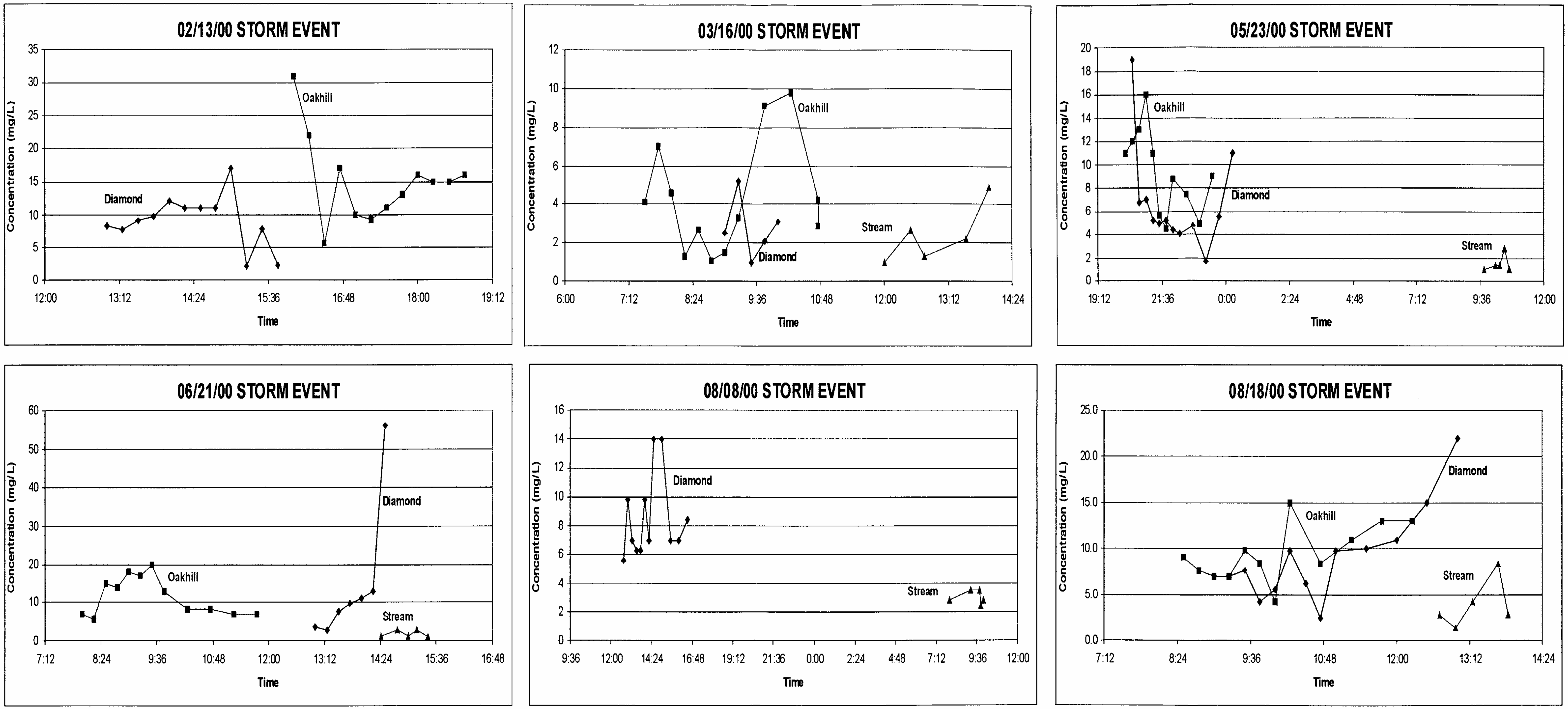
EXHIBIT 31



TOTAL KJELDAHL NITROGEN CONCENTRATIONS FOR ALL STORM EVENTS
PIGEON CREEK WATERSHED DIAGNOSTIC STUDY
EVANSVILLE WATER AND SEWER UTILITY AND
FOUR RIVERS RESOURCE CONSERVATION AND DEVELOPMENT AREA, INC.
Pigeon Creek, Indiana

HARZA ENGINEERING COMPANY
WATER & ENVIRONMENT

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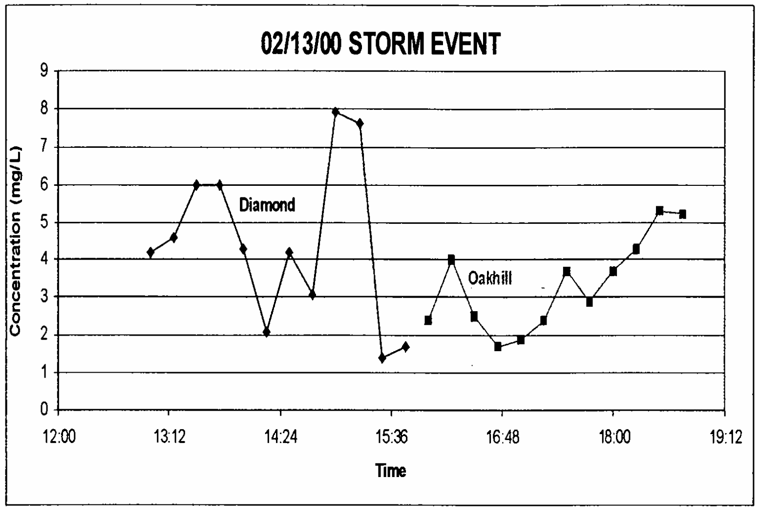
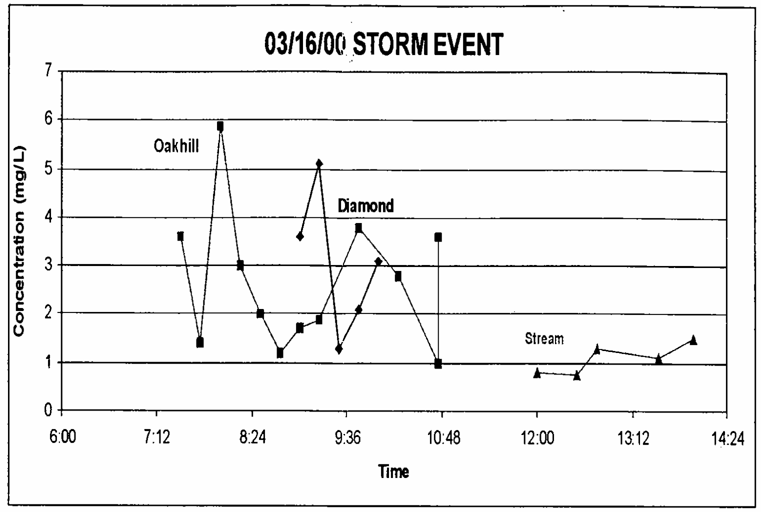
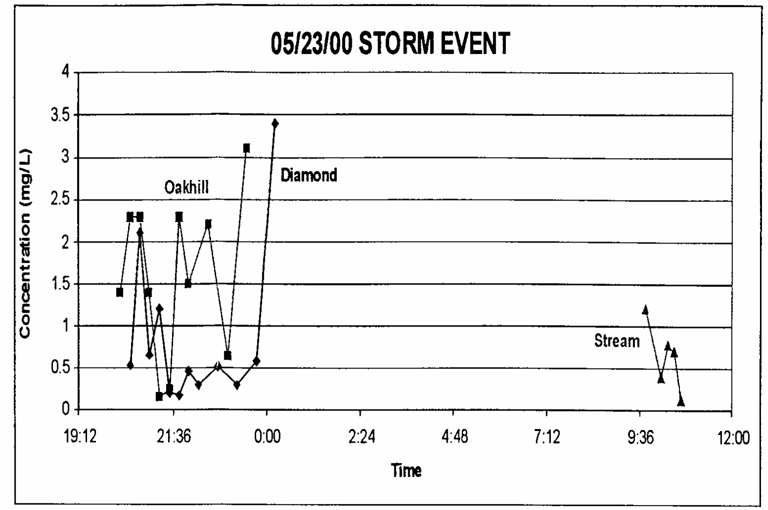
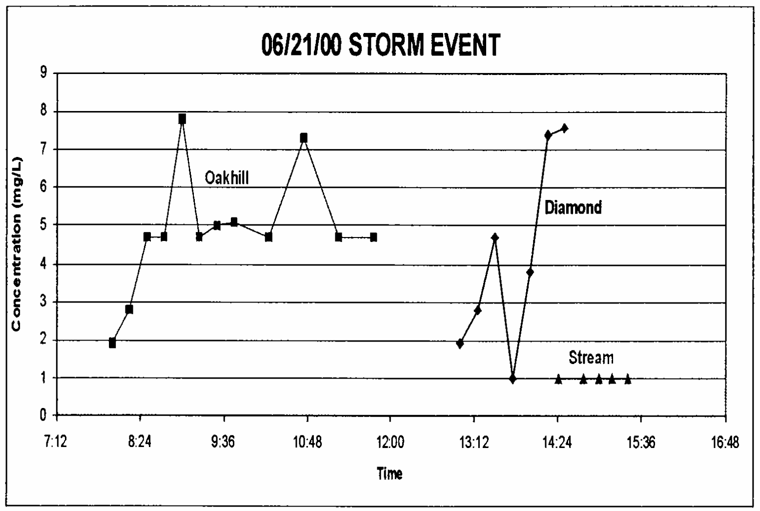
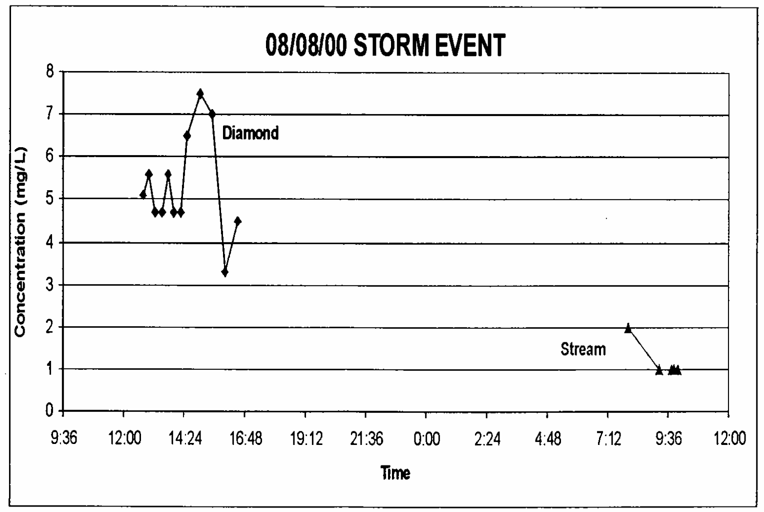
EXHIBIT 32

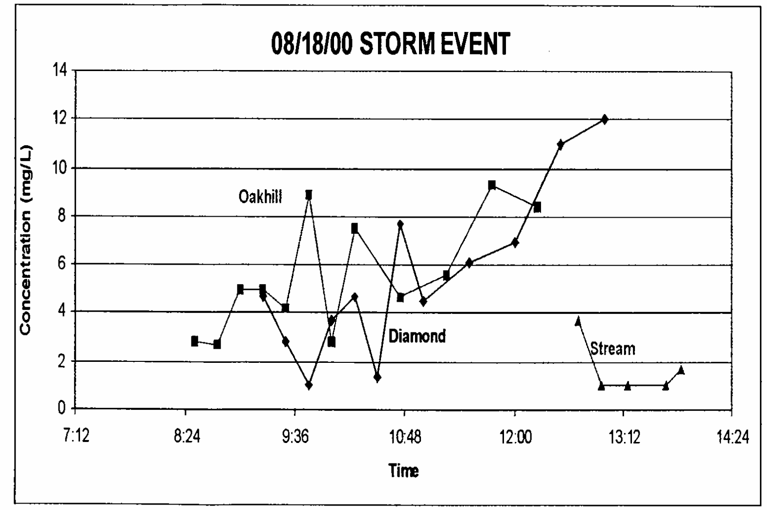












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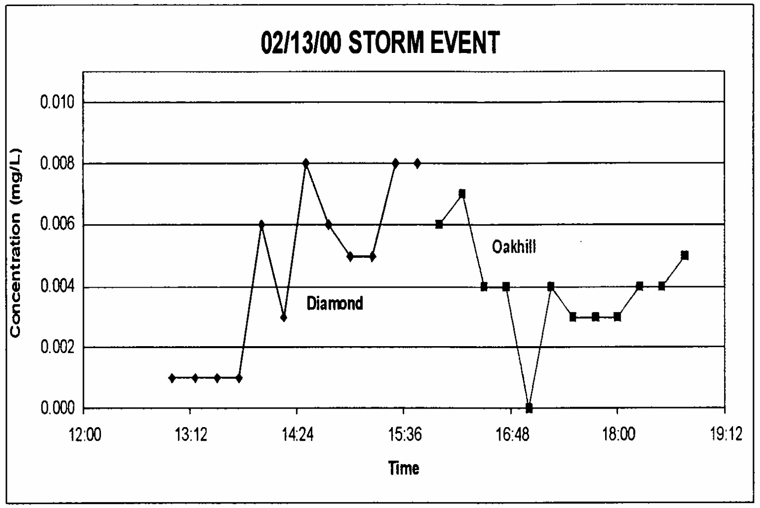
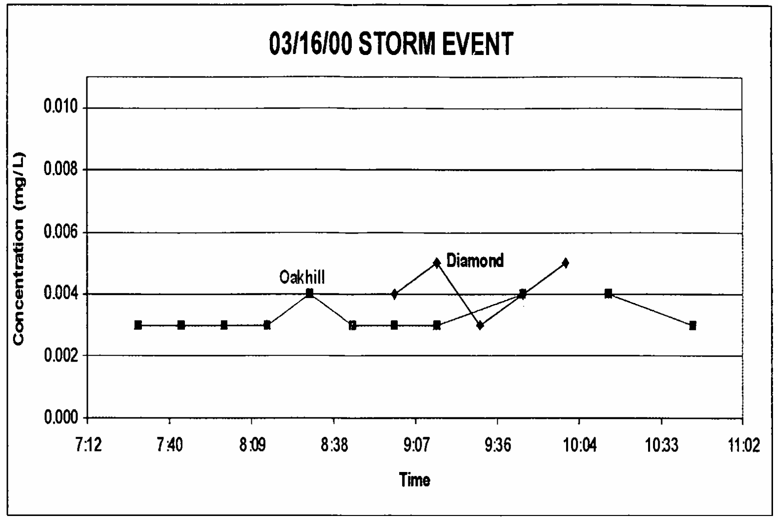
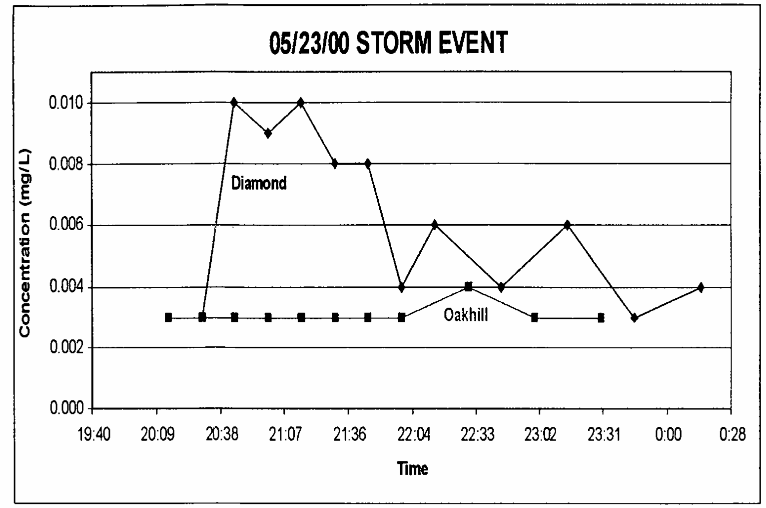
HARZA ENGINEERING COMPANY
WATER & ENVIRONMENT

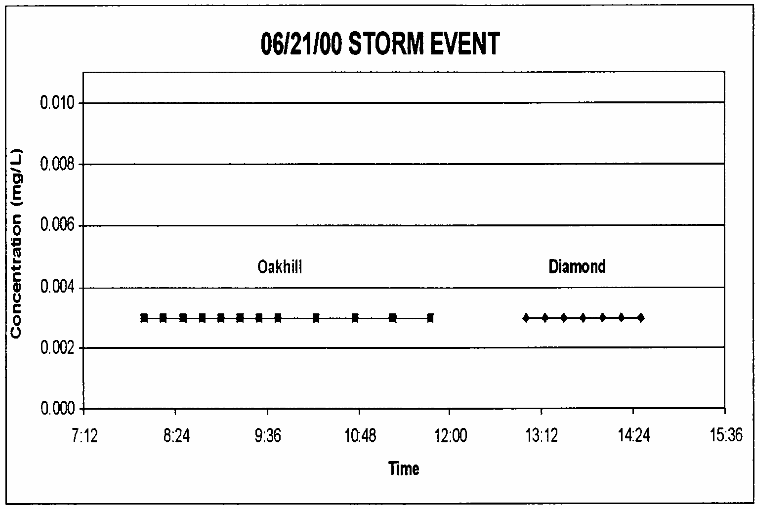
AMMONIA CONCENTRATIONS FOR ALL STORM EVENTS
PIGEON CREEK WATERSHED DIAGNOSTIC STUDY
EVANSVILLE WATER AND SEWER UTILITY AND
FOUR RIVERS RESOURCE CONSERVATION AND DEVELOPMENT AREA, INC.
Pigeon Creek, Indiana

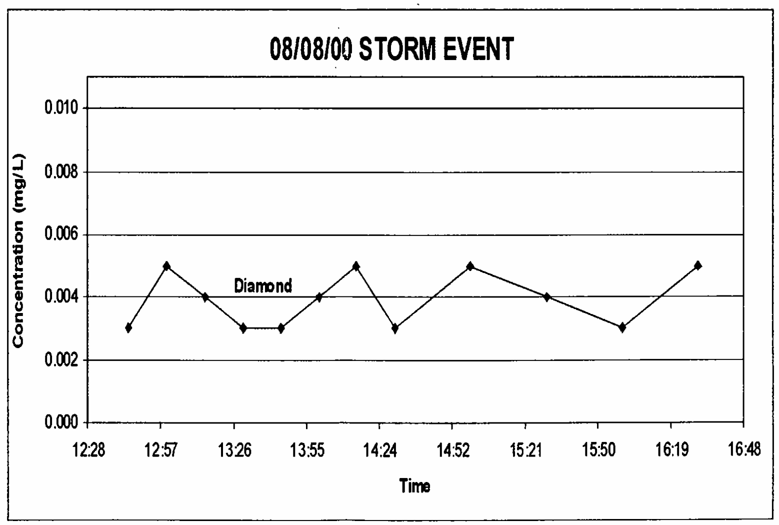
EXHIBIT 33

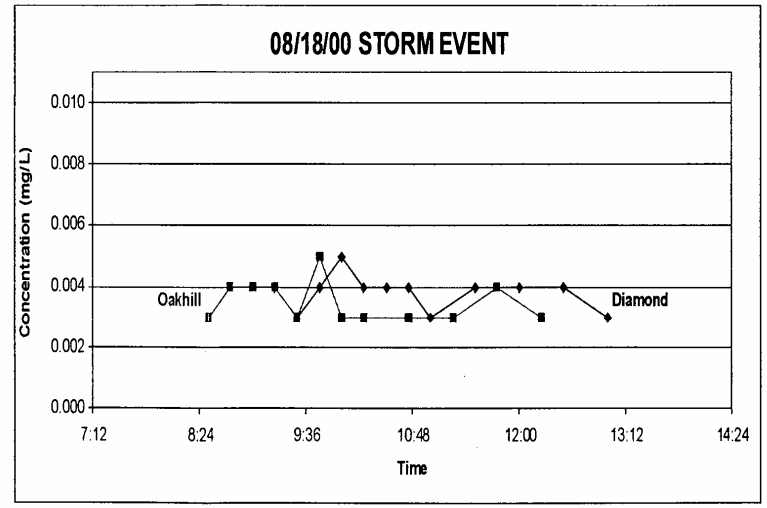










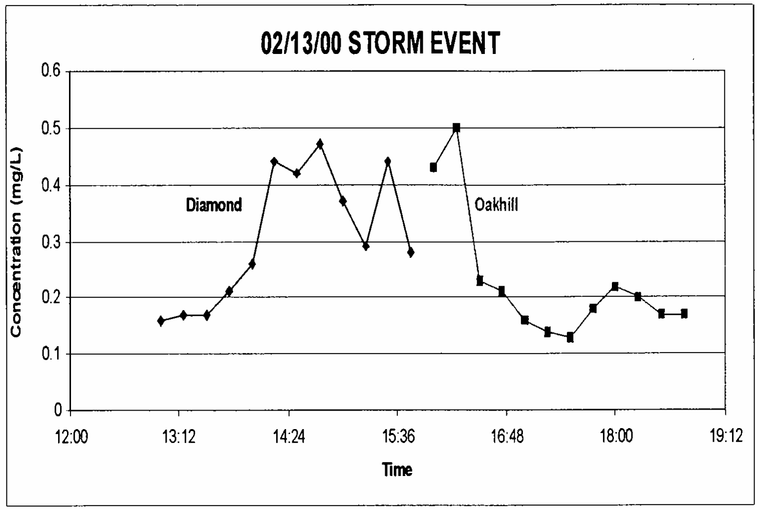


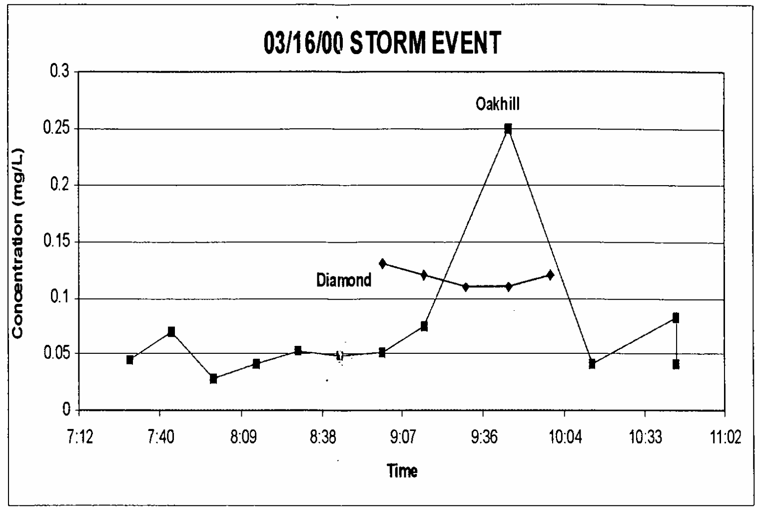
O:/pigeon creek/pigeon-ex33.cdr

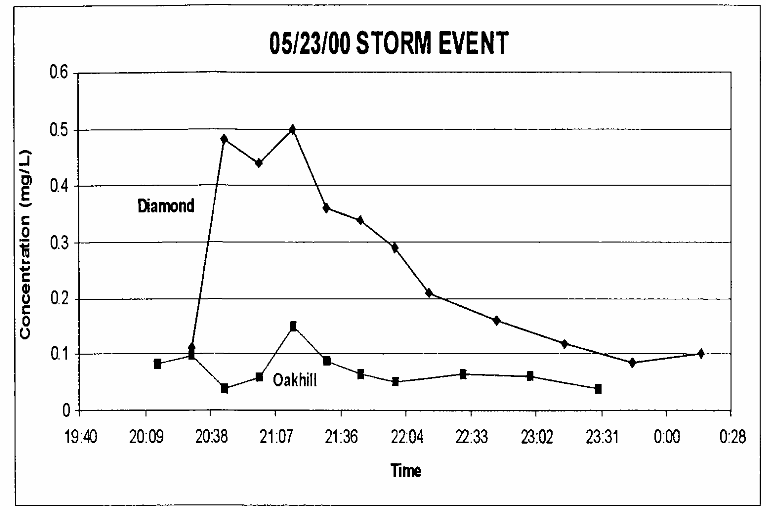
HARZA ENGINEERING COMPANY
WATER & ENVIRONMENT

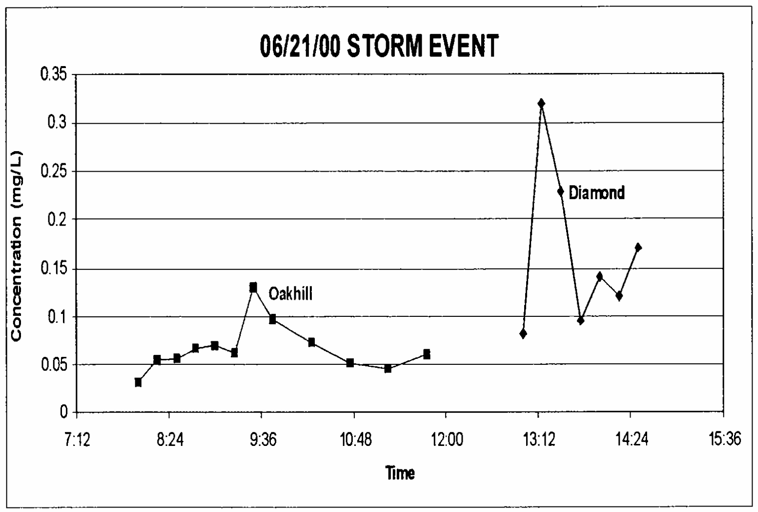
ARSENIC CONCENTRATIONS FOR ALL STORM EVENTS
PIGEON CREEK WATERSHED DIAGNOSTIC STUDY
EVANSVILLE WATER AND SEWER UTILITY AND
FOUR RIVERS RESOURCE CONSERVATION AND DEVELOPMENT AREA, INC.
Pigeon Creek, Indiana

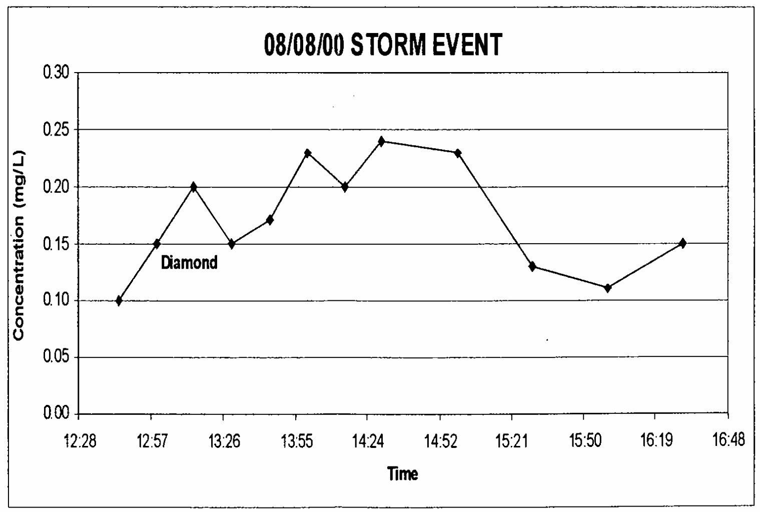
EXHIBIT 34

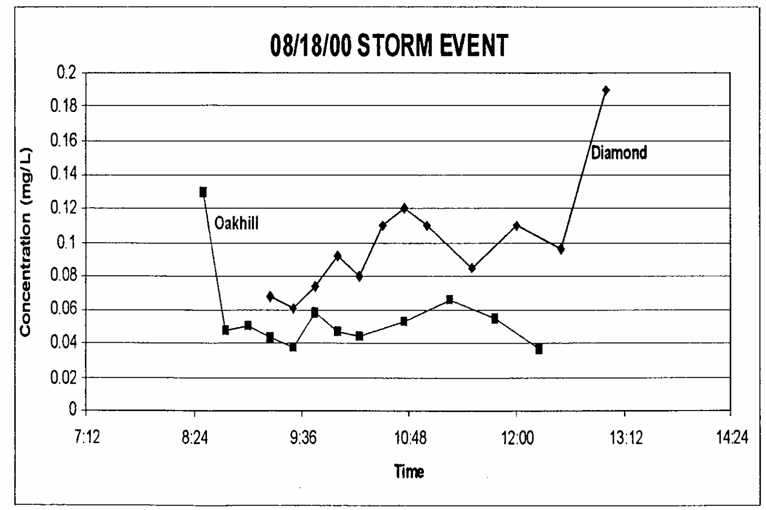












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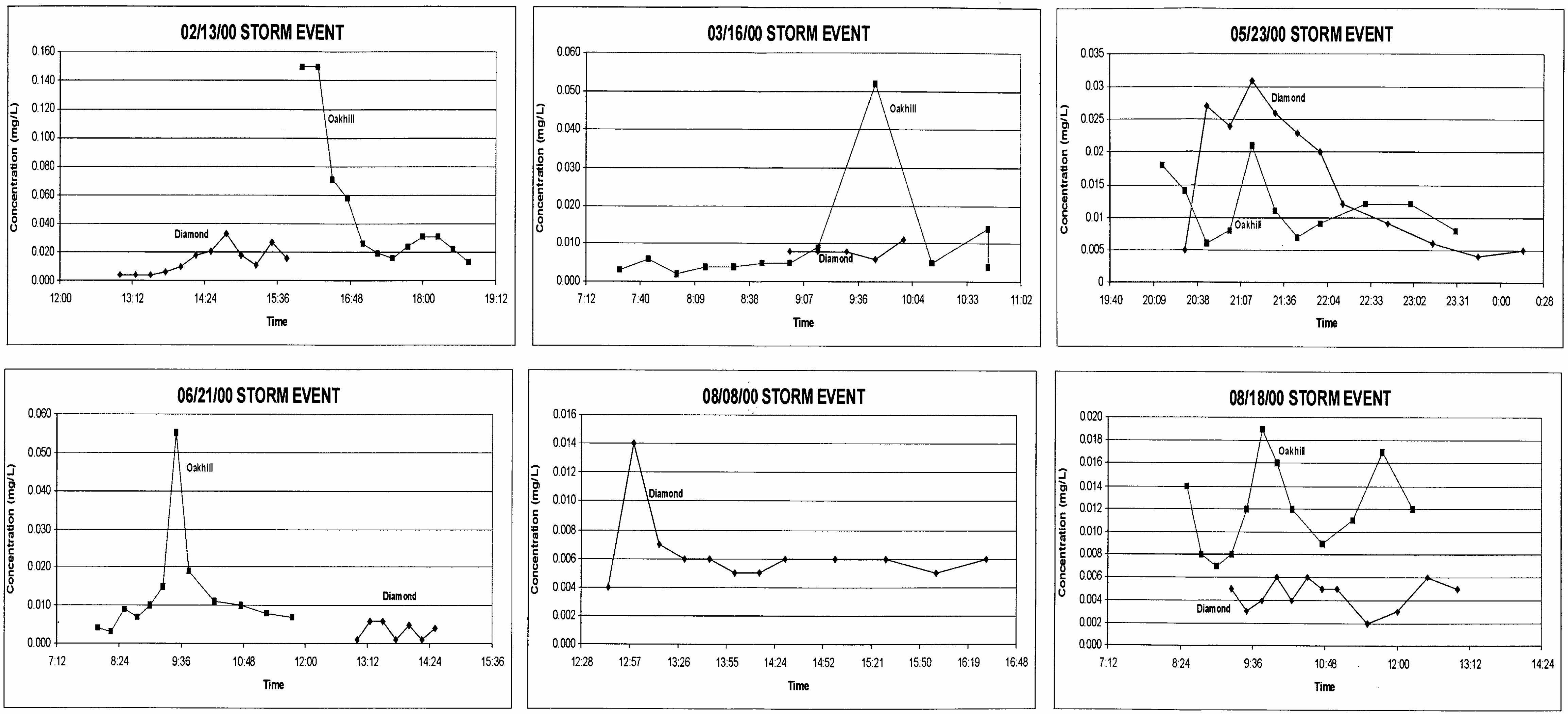
HARZA ENGINEERING COMPANY
WATER & ENVIRONMENT

ZINC CONCENTRATIONS FOR ALL STORM EVENTS
PIGEON CREEK WATERSHED DIAGNOSTIC STUDY
EVANSVILLE WATER AND SEWER UTILITY AND
FOUR RIVERS RESOURCE CONSERVATION AND DEVELOPMENT AREA, INC.
Pigeon Creek, Indiana

EXHIBIT 35



CHROMIUM CONCENTRATIONS FOR ALL STORM EVENTS
PIGEON CREEK WATERSHED DIAGNOSTIC STUDY
EVANSVILLE WATER AND SEWER UTILITY AND
FOUR RIVERS RESOURCE CONSERVATION AND DEVELOPMENT AREA, INC.
Pigeon Creek, Indiana

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WATER & ENVIRONMENT

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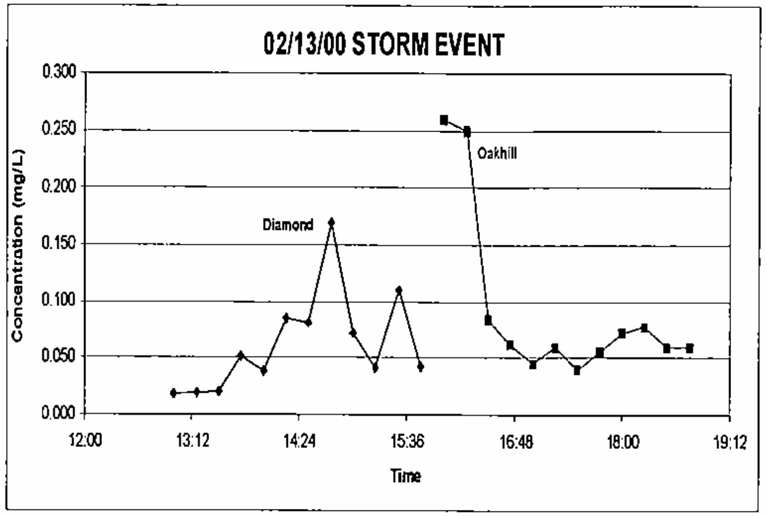
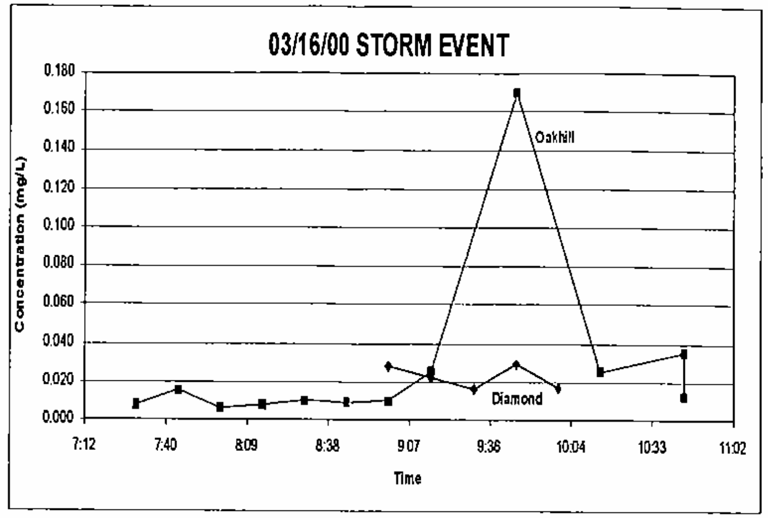
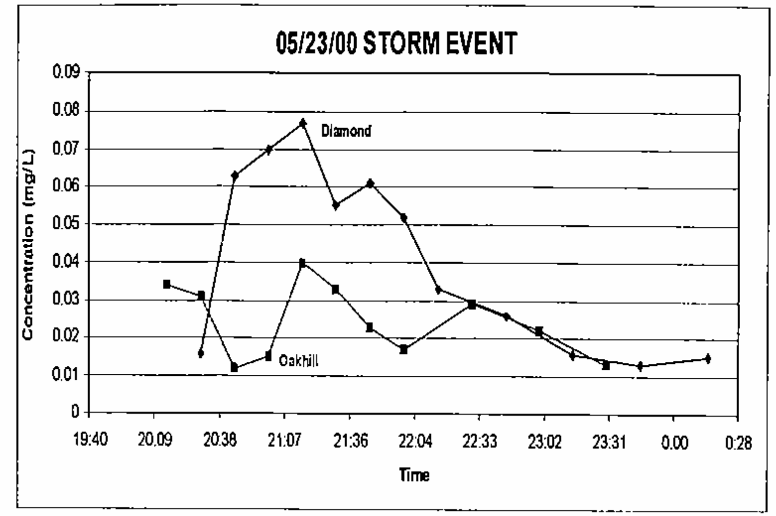
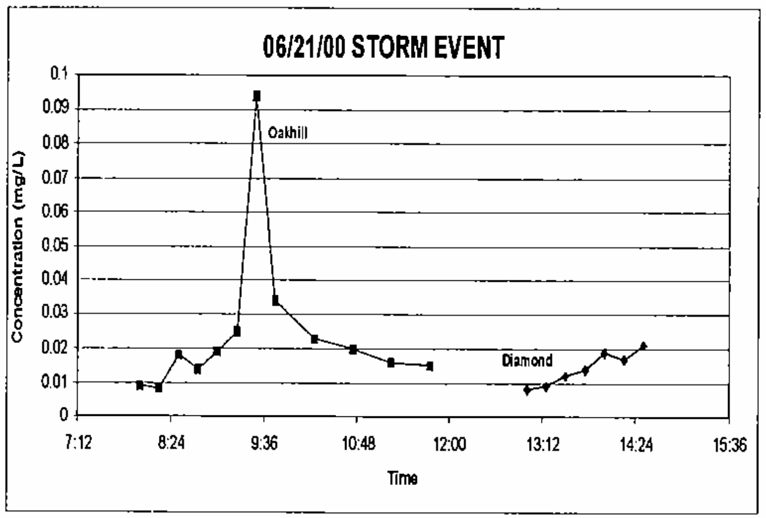
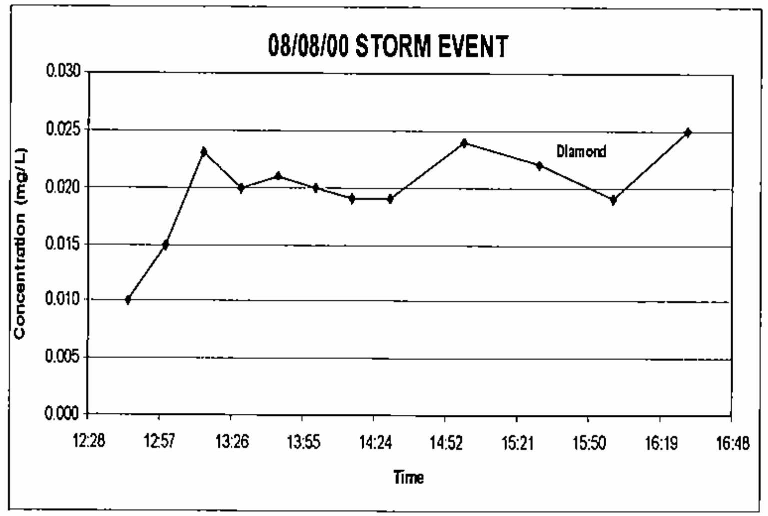
EXHIBIT 36

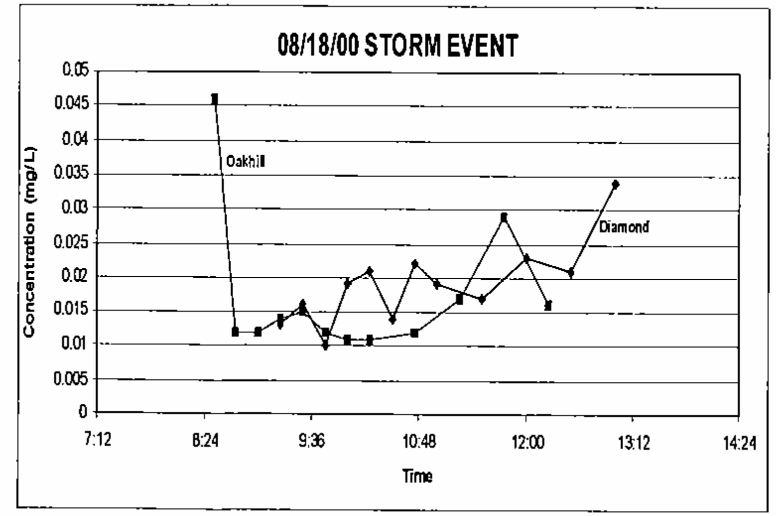












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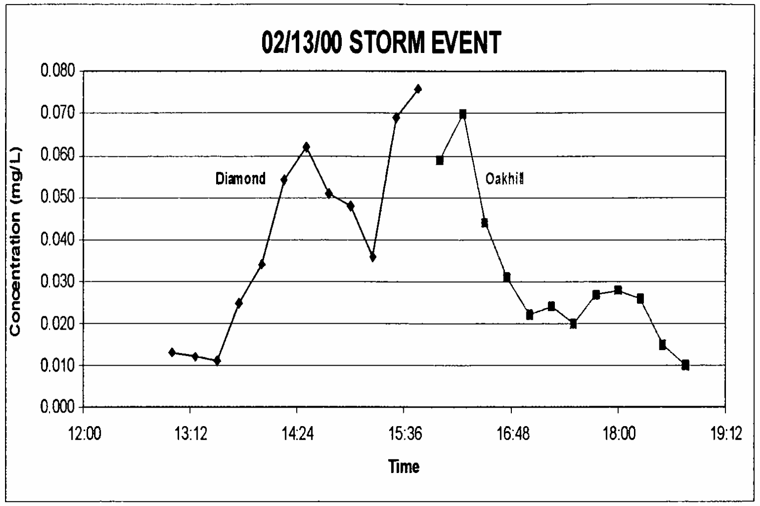
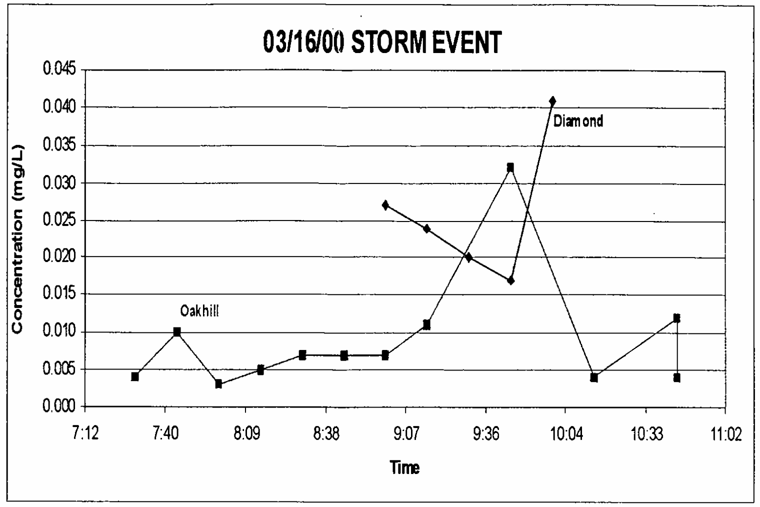
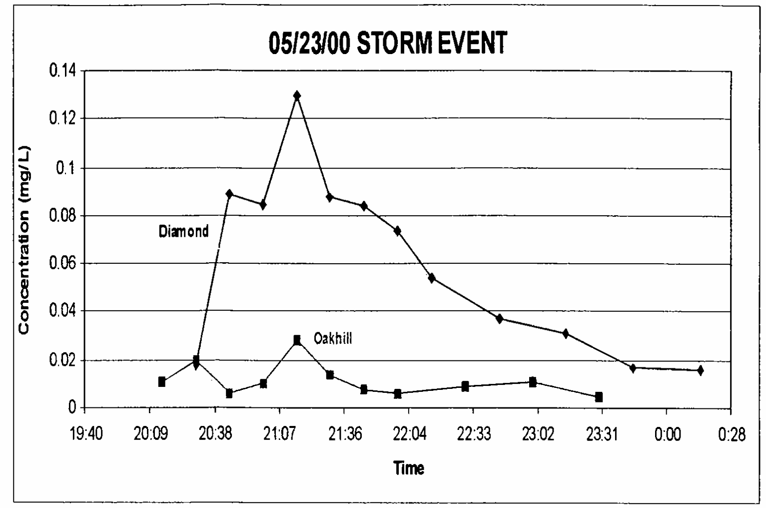
HARZA ENGINEERING COMPANY
WATER & ENVIRONMENT

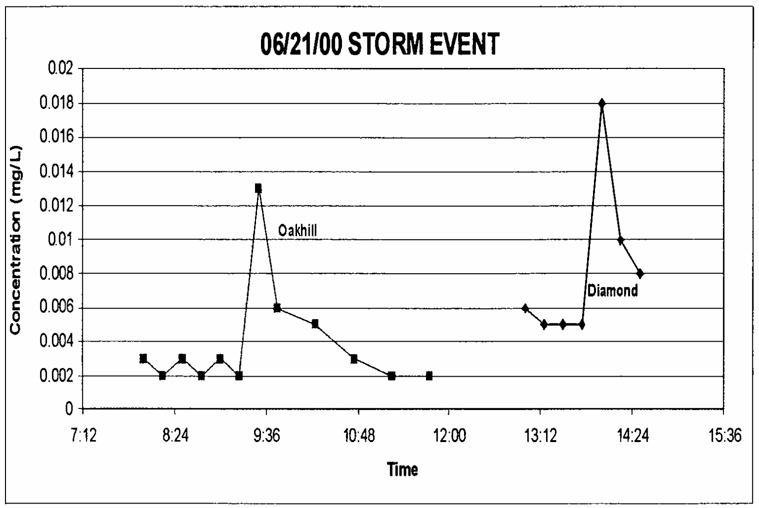
COPPER CONCENTRATIONS FOR ALL STORM EVENTS
PIGEON CREEK WATERSHED DIAGNOSTIC STUDY
EVANSVILLE WATER AND SEWER UTILITY AND
FOUR RIVERS RESOURCE CONSERVATION AND DEVELOPMENT AREA, INC.
Pigeon Creek, Indiana

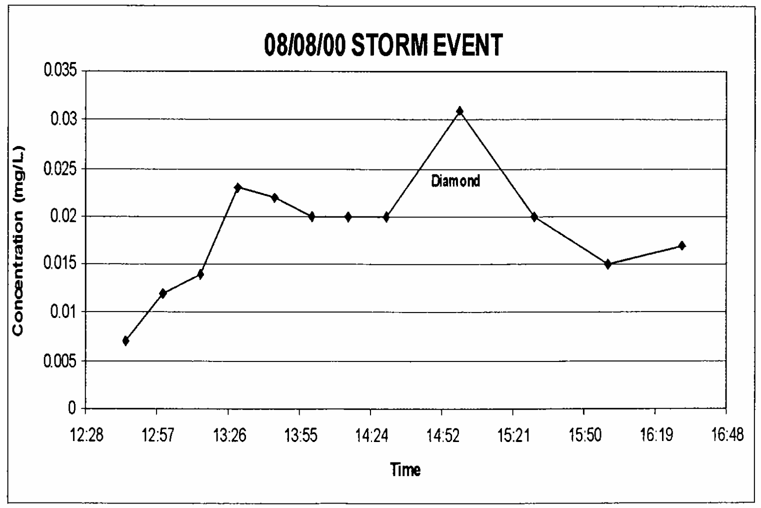
EXHIBIT 37

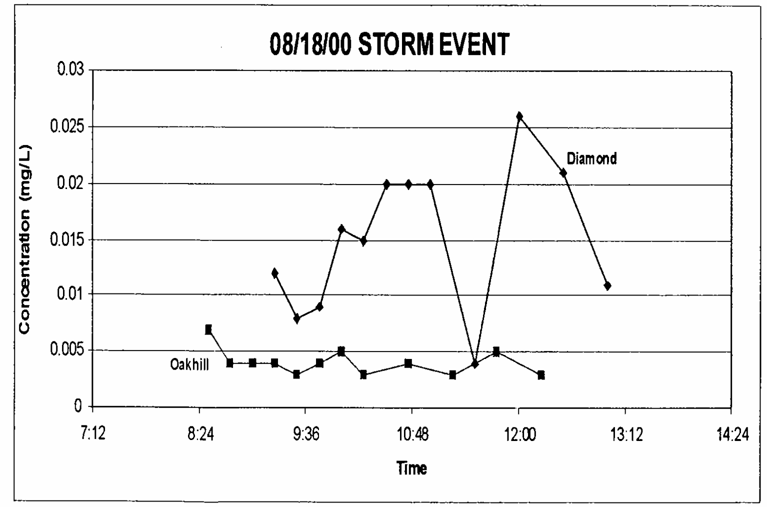












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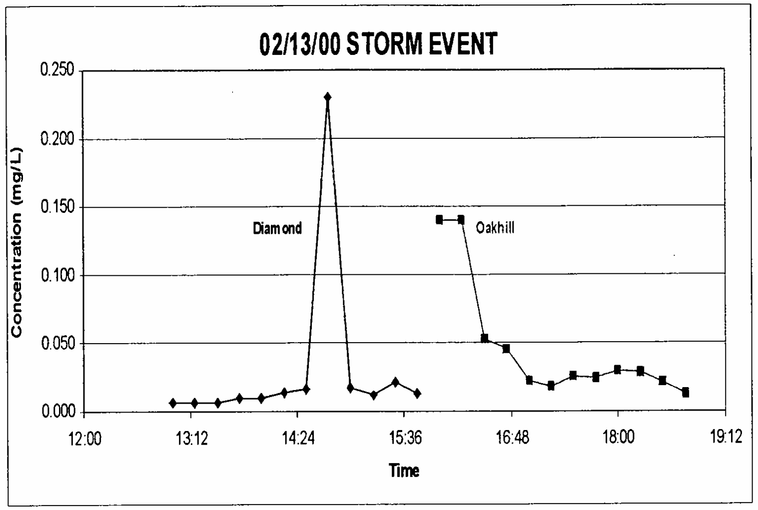
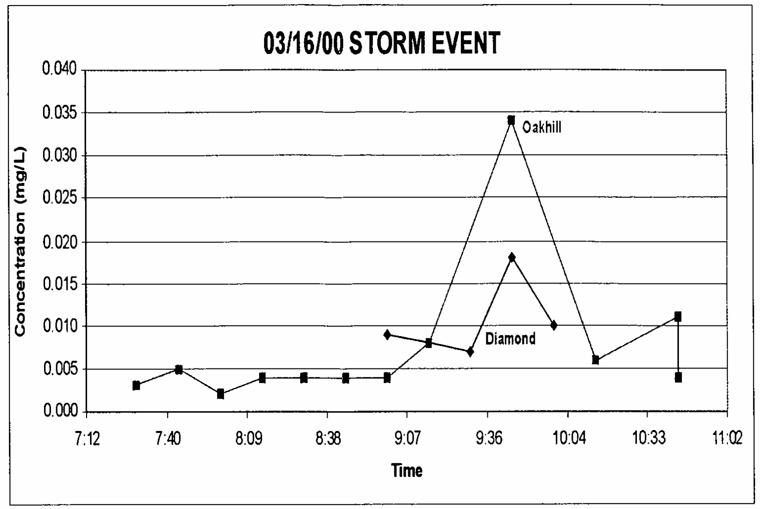
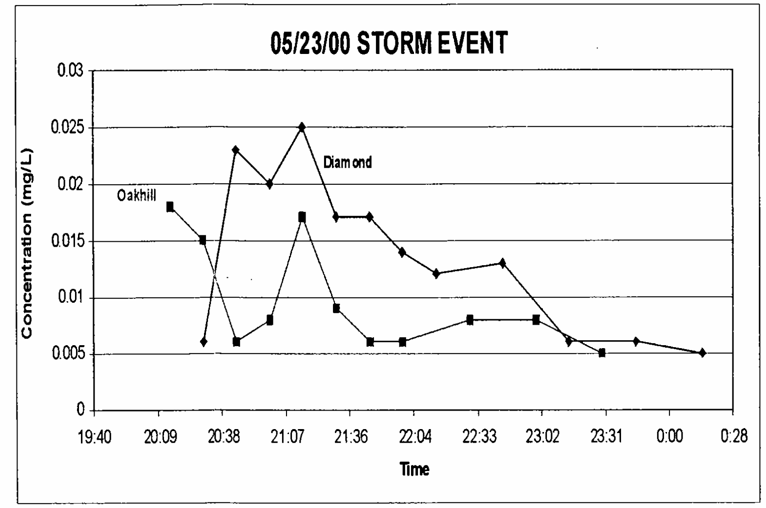
HARZA ENGINEERING COMPANY
WATER & ENVIRONMENT

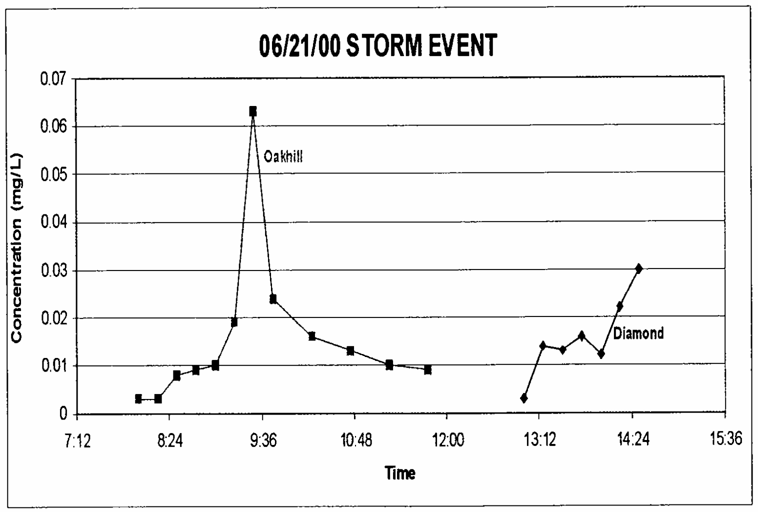
LEAD CONCENTRATIONS FOR ALL STORM EVENTS
PIGEON CREEK WATERSHED DIAGNOSTIC STUDY
EVANSVILLE WATER AND SEWER UTILITY AND
FOUR RIVERS RESOURCE CONSERVATION AND DEVELOPMENT AREA, INC.
Pigeon Creek, Indiana

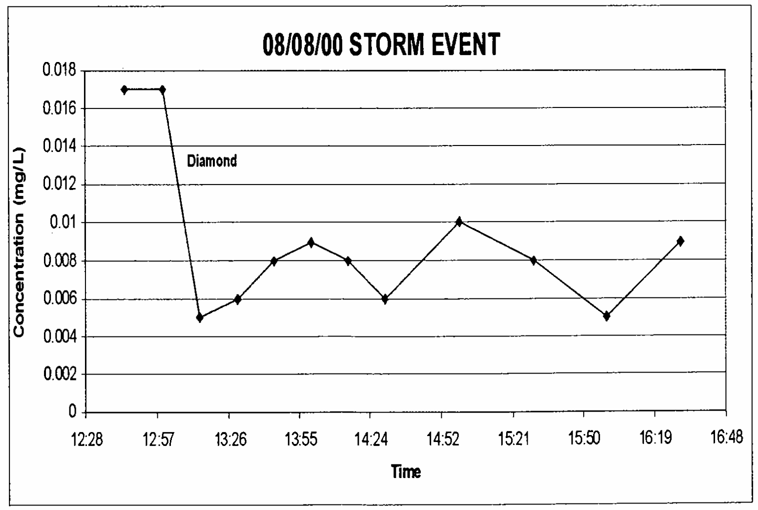
EXHIBIT 38

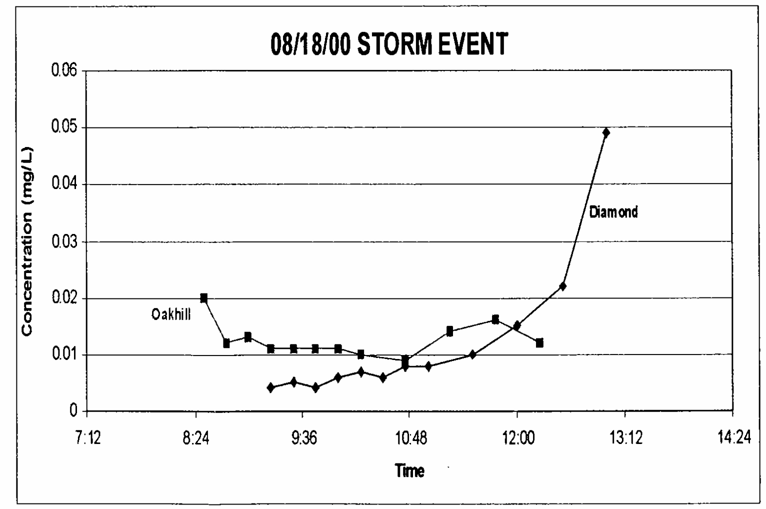












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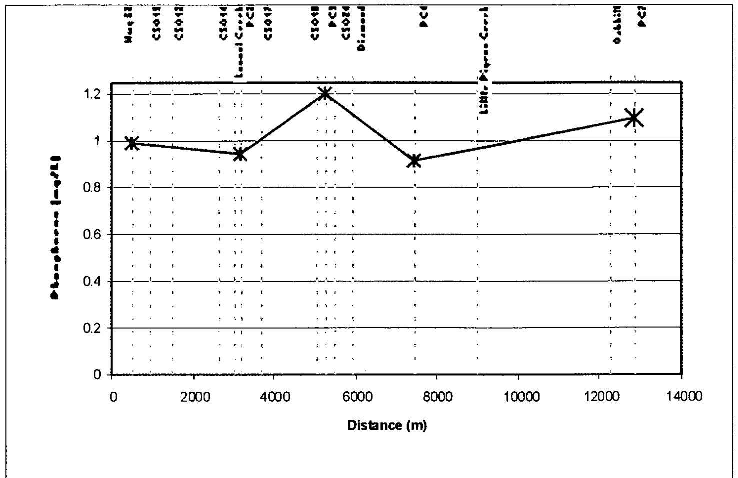
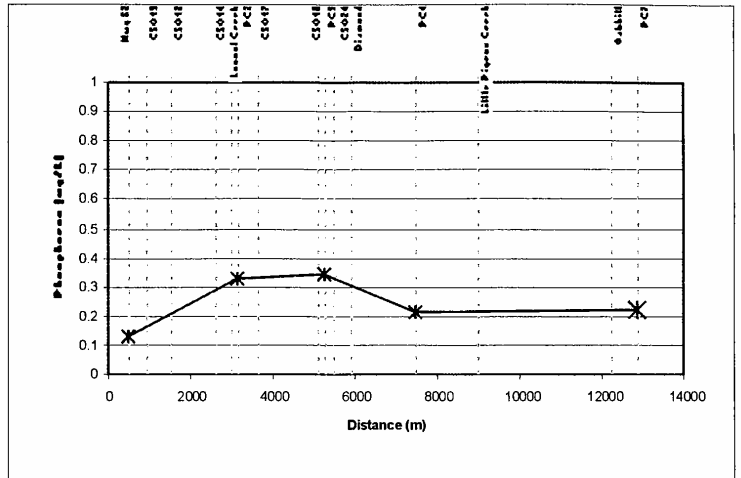
HARZA ENGINEERING COMPANY
WATER & ENVIRONMENT

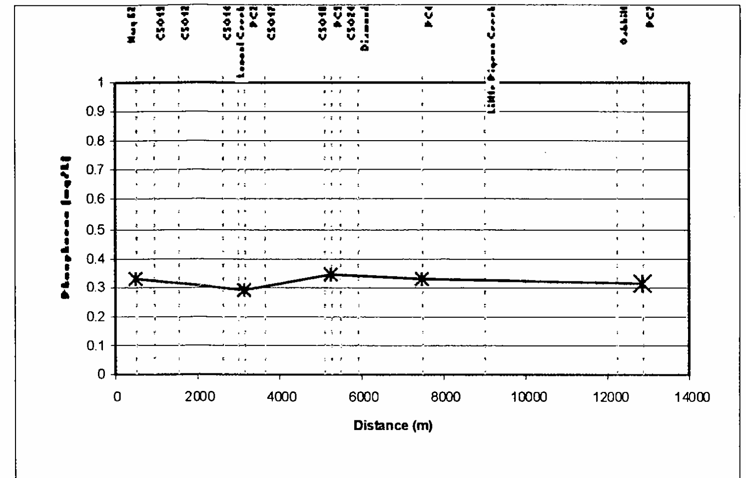
NICKEL CONCENTRATIONS FOR ALL STORM EVENTS
PIGEON CREEK WATERSHED DIAGNOSTIC STUDY
EVANSVILLE WATER AND SEWER UTILITY AND
FOUR RIVERS RESOURCE CONSERVATION AND DEVELOPMENT AREA, INC.
Pigeon Creek, Indiana



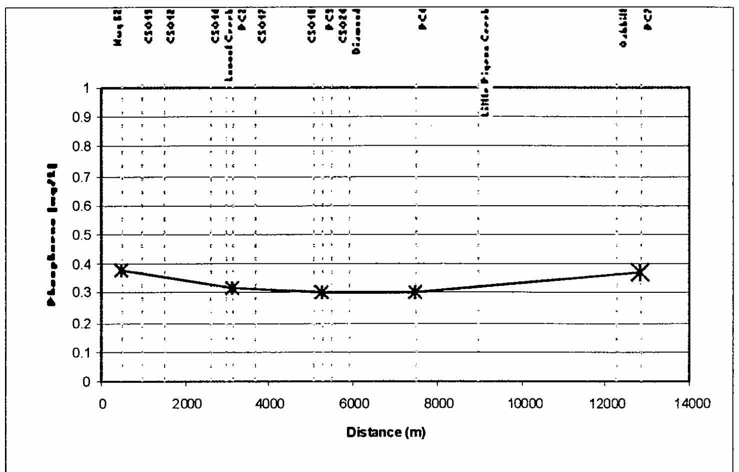
03/16/00 STORM EVENT



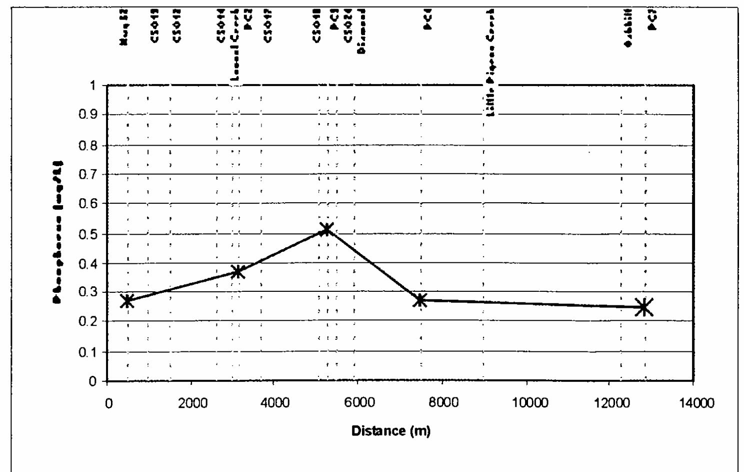
05/23/00 STORM EVENT



06/21/00 STORM EVENT



08/08/00 STORM EVENT



08/18/00 STORM EVENT

PHOSPHOROUS CONCENTRATIONS OVER STREAM LENGTH

PIGEON CREEK WATERSHED DIAGNOSTIC STUDY
EVANSVILLE WATER AND SEWER UTILITY AND
FOUR RIVERS RESOURCE CONSERVATION AND DEVELOPMENT AREA, INC.
Pigeon Creek, Indiana

HARZA ENGINEERING COMPANY
WATER & ENVIRONMENT

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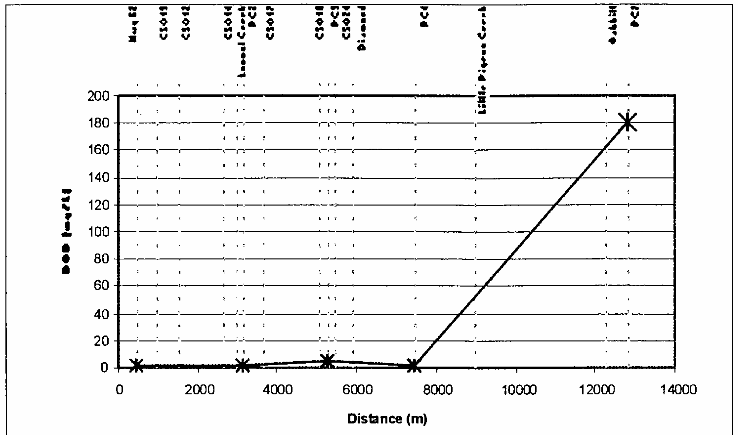
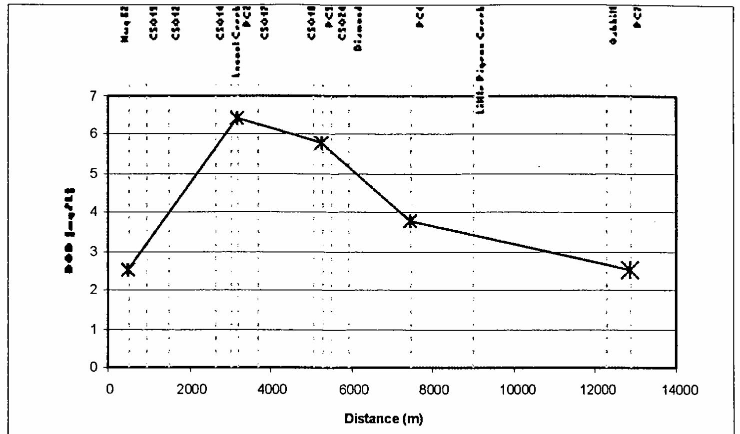
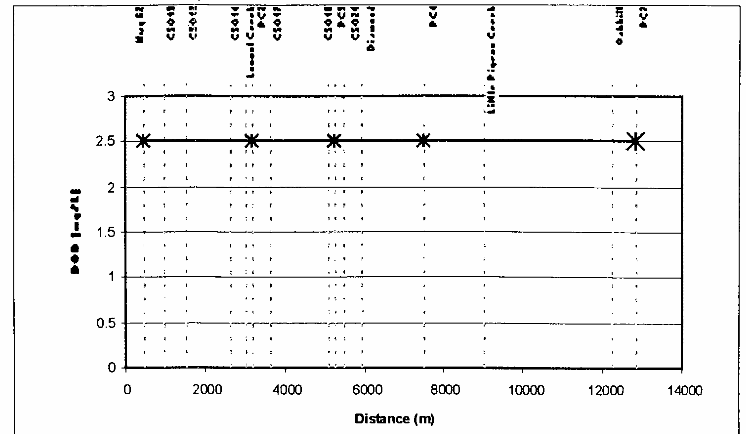
EXHIBIT 40



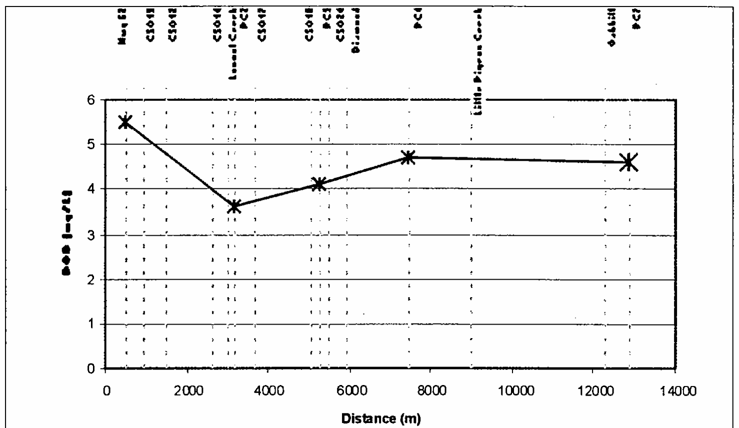
03/16/00 STORM EVENT



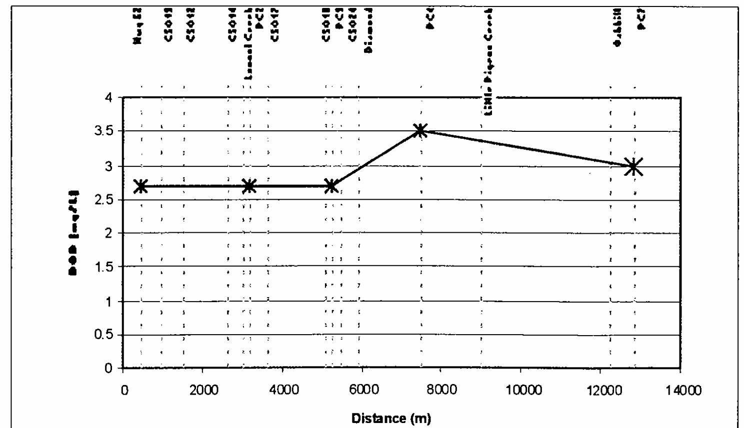
05/23/00 STORM EVENT



06/21/00 STORM EVENT



08/08/00 STORM EVENT



08/18/00 STORM EVENT

BOD CONCENTRATIONS OVER STREAM LENGTH
PIGEON CREEK WATERSHED DIAGNOSTIC STUDY
EVANSVILLE WATER AND SEWER UTILITY AND
FOUR RIVERS RESOURCE CONSERVATION AND DEVELOPMENT AREA, INC.
Pigeon Creek, Indiana

HARZA ENGINEERING COMPANY
WATER & ENVIRONMENT

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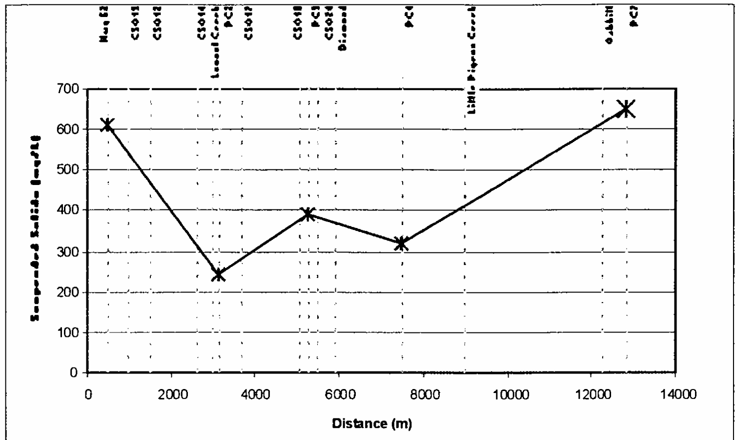
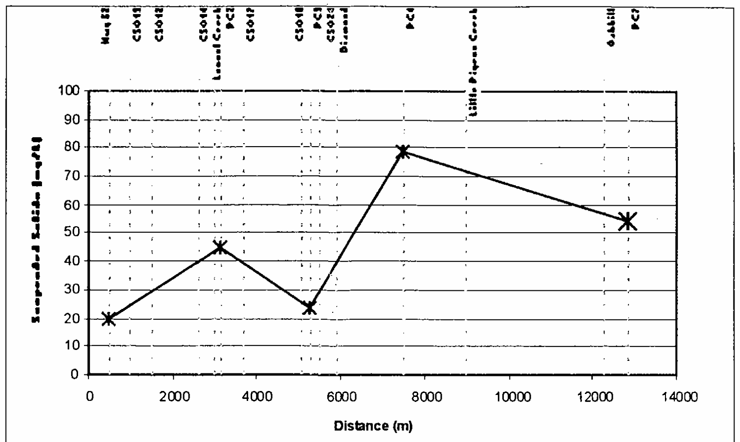
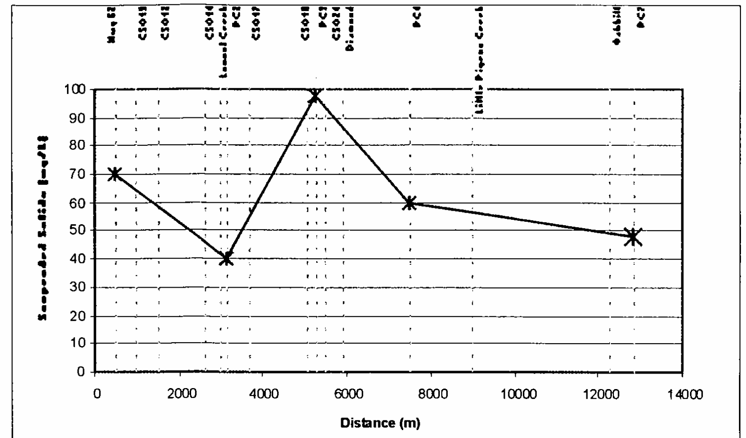
EXHIBIT 41



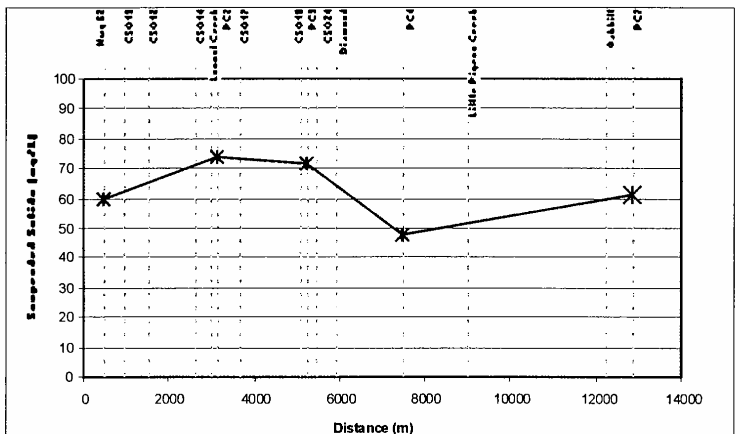
03/16/00 STORM EVENT



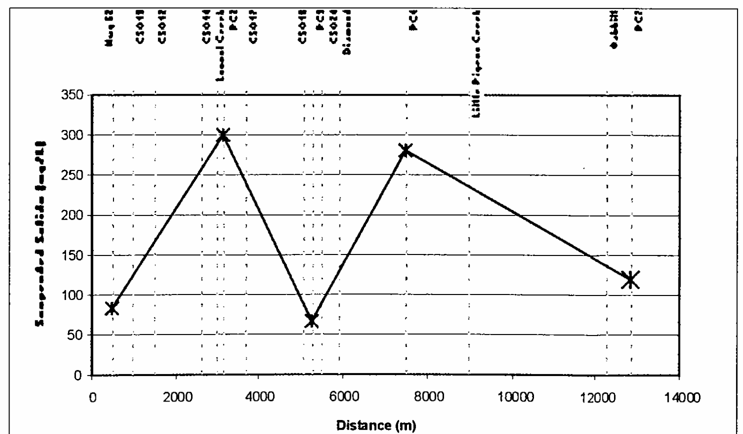
05/23/00 STORM EVENT



06/21/00 STORM EVENT



08/18/00 STORM EVENT



08/08/00 STORM EVENT

SUSPENDED SOLIDS CONCENTRATIONS OVER STREAM LENGTH
PIGEON CREEK WATERSHED DIAGNOSTIC STUDY
EVANSVILLE WATER AND SEWER UTILITY AND
FOUR RIVERS RESOURCE CONSERVATION AND DEVELOPMENT AREA, INC.
Pigeon Creek, Indiana

HARZA ENGINEERING COMPANY
WATER & ENVIRONMENT

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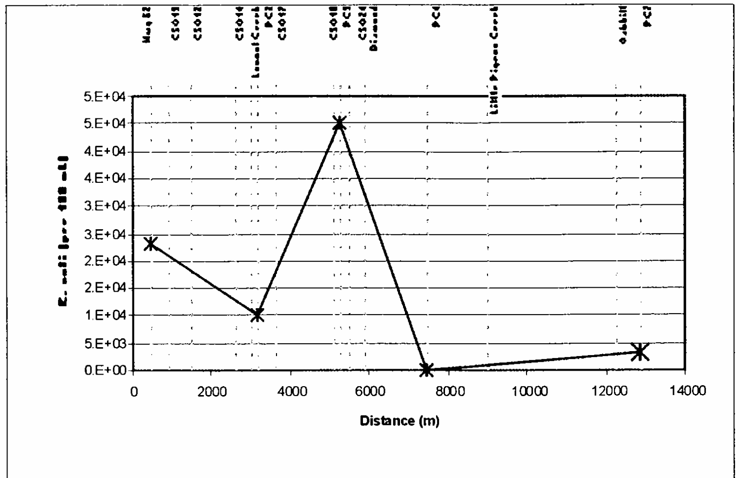
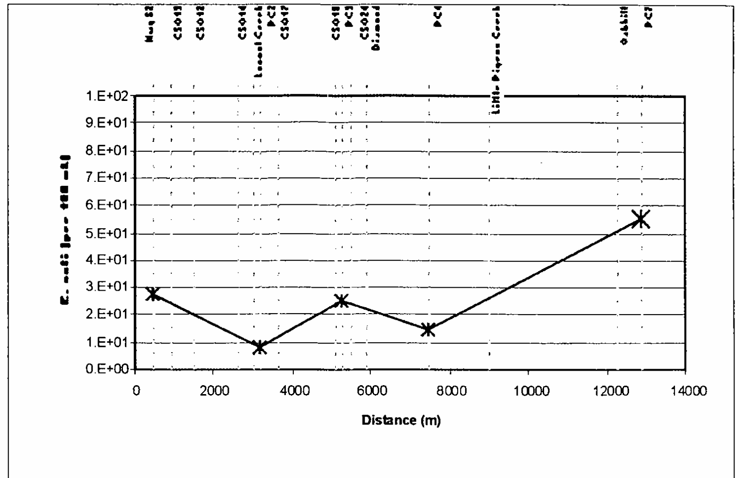
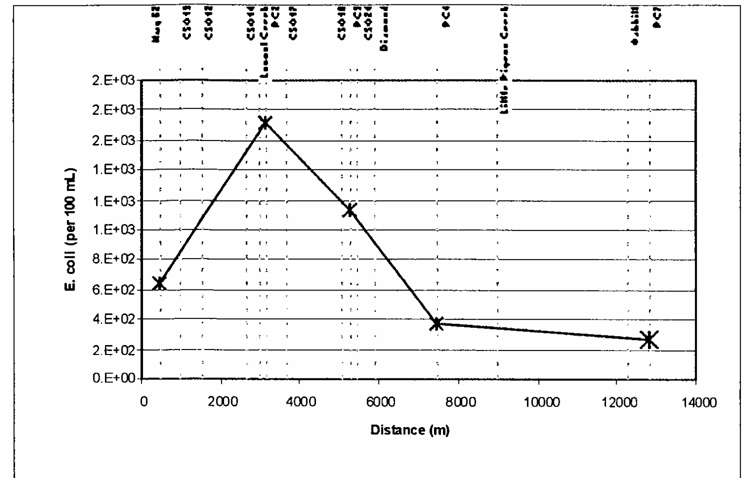
EXHIBIT 42



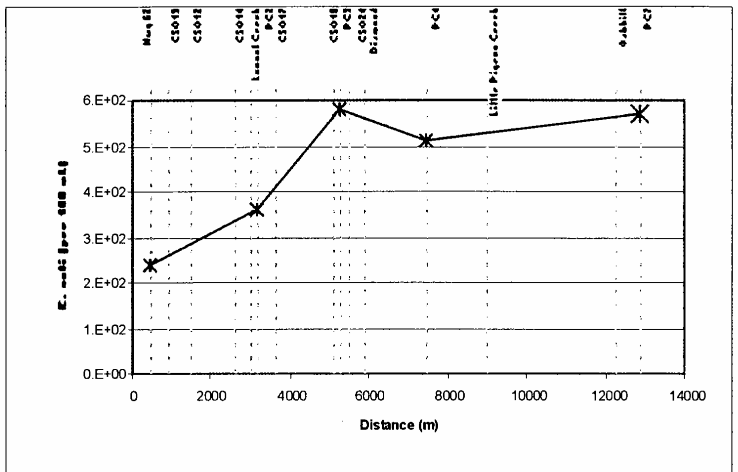
03/16/00 STORM EVENT



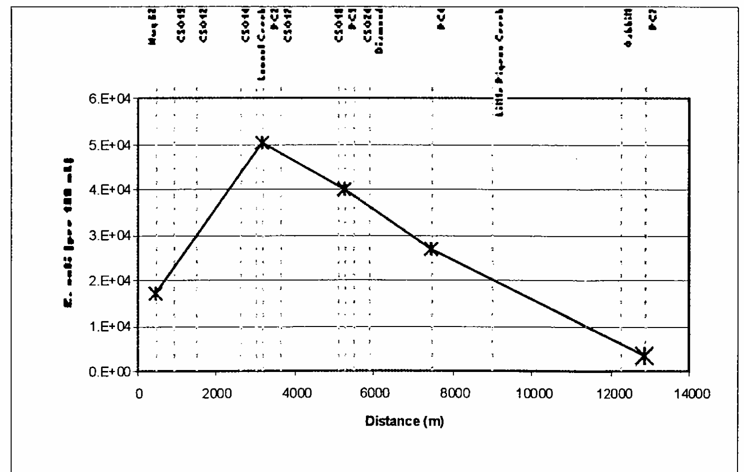
05/23/00 STORM EVENT



06/21/00 STORM EVENT



08/08/00 STORM EVENT



08/18/00 STORM EVENT

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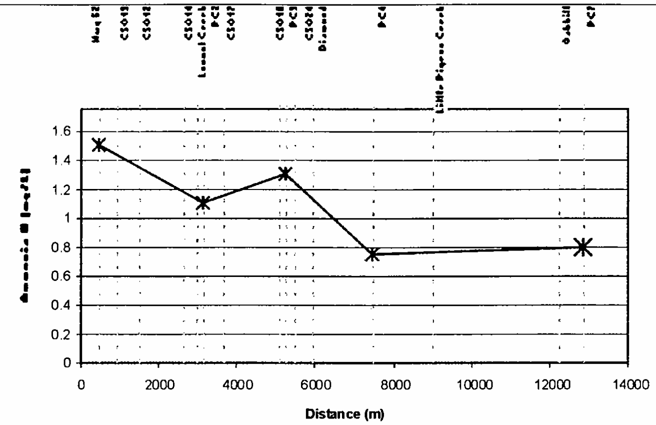
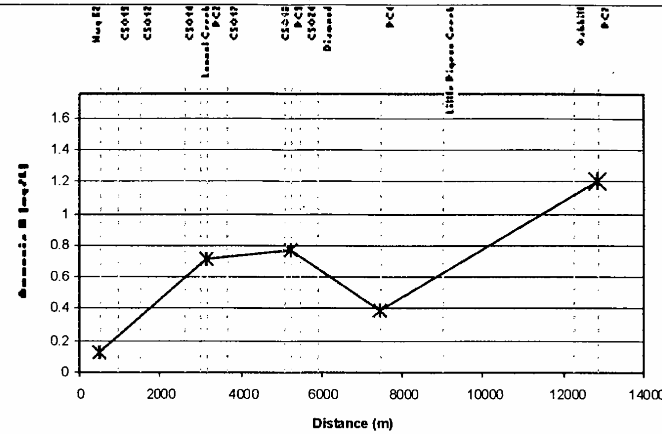
HARZA ENGINEERING COMPANY
WATER & ENVIRONMENT

E.COLI CONCENTRATIONS OVER STREAM LENGTH
PIGEON CREEK WATERSHED DIAGNOSTIC STUDY
EVANSVILLE WATER AND SEWER UTILITY AND
FOUR RIVERS RESOURCE CONSERVATION AND DEVELOPMENT AREA, INC.
Pigeon Creek, Indiana

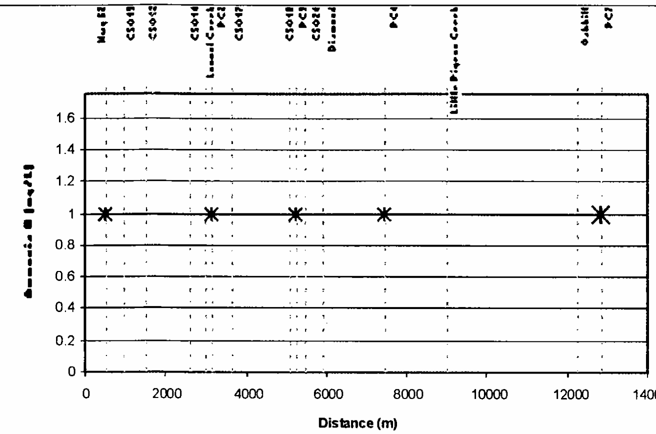
EXHIBIT 43



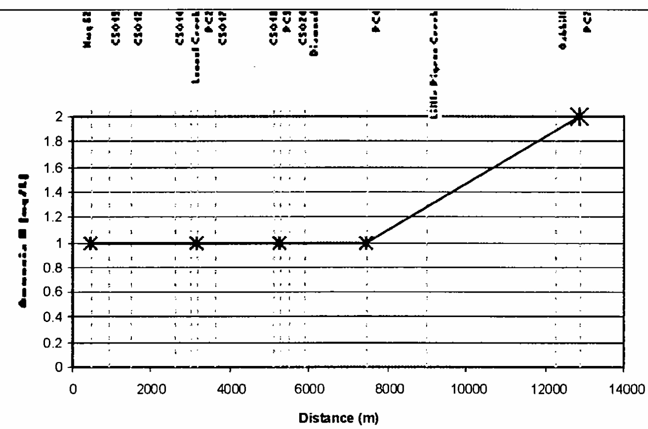
03/16/00 STORM EVENT



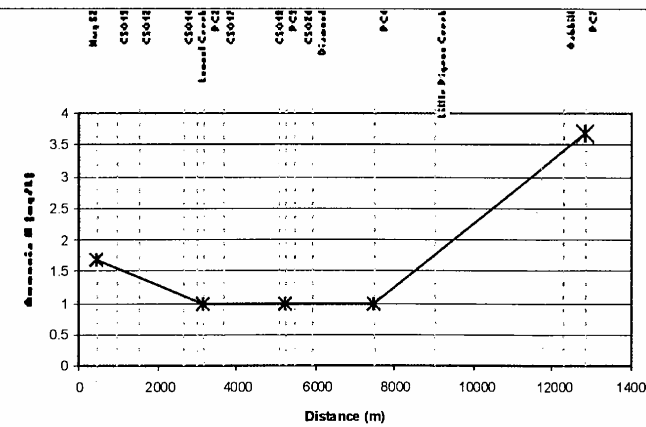
05/23/00 STORM EVENT



06/21/00 STORM EVENT



08/08/00 STORM EVENT

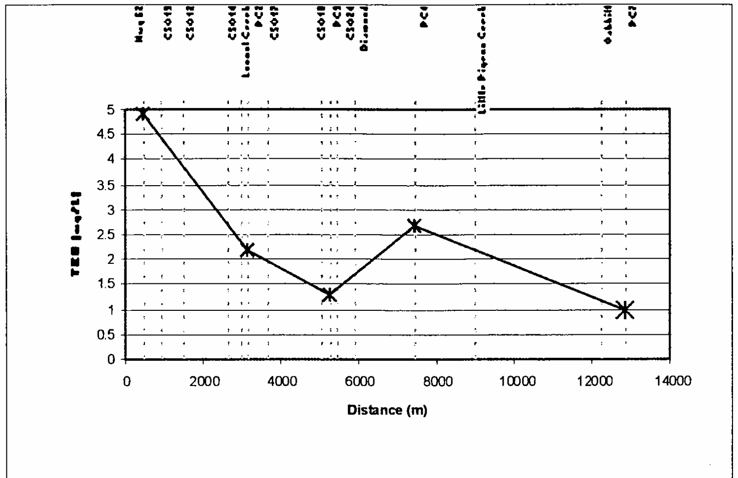


08/18/00 STORM EVENT

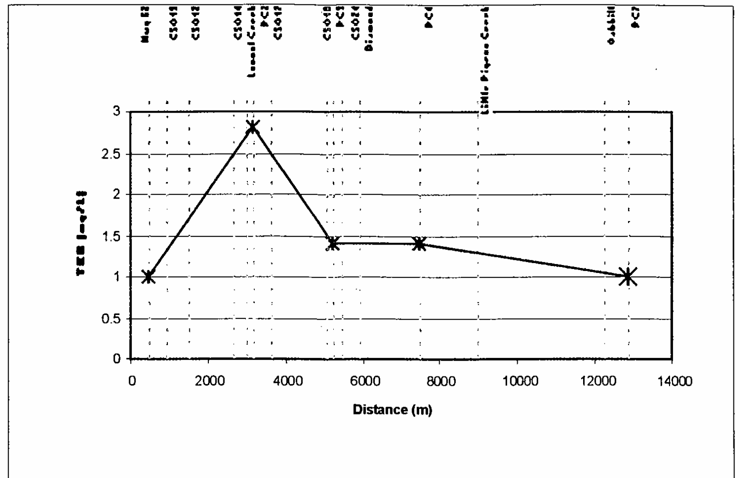
AMMONIA CONCENTRATIONS OVER STREAM LENGTH
PIGEON CREEK WATERSHED DIAGNOSTIC STUDY
EVANSVILLE WATER AND SEWER UTILITY AND
FOUR RIVERS RESOURCE CONSERVATION AND DEVELOPMENT AREA, INC.
Pigeon Creek, Indiana

HARZA ENGINEERING COMPANY
WATER & ENVIRONMENT

EXHIBIT 44



03/16/00 STORM EVENT



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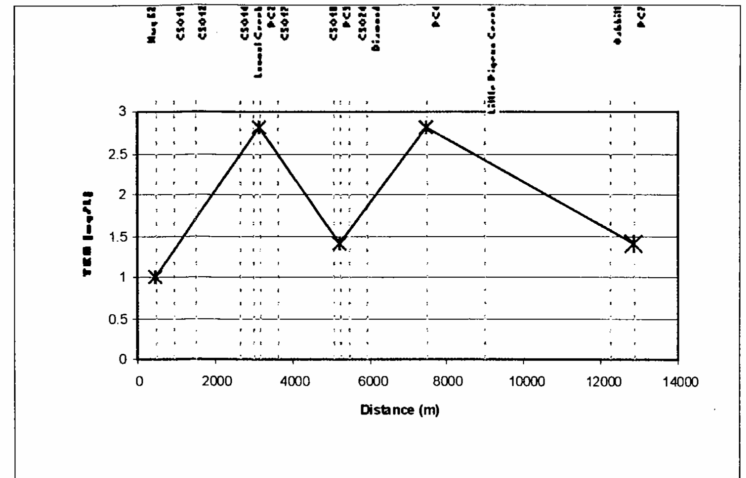
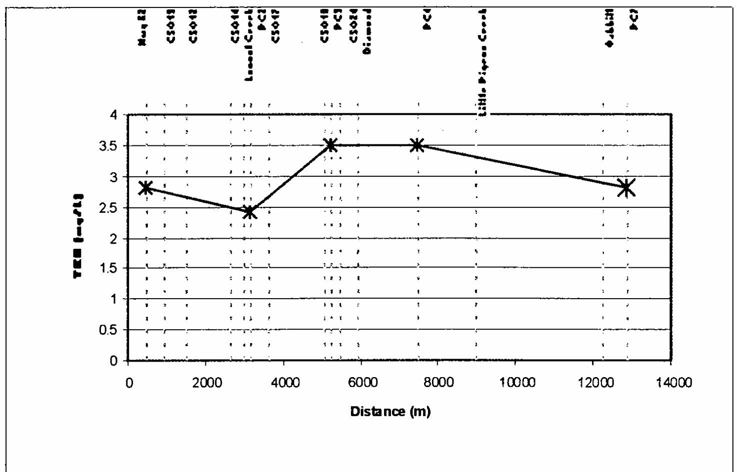
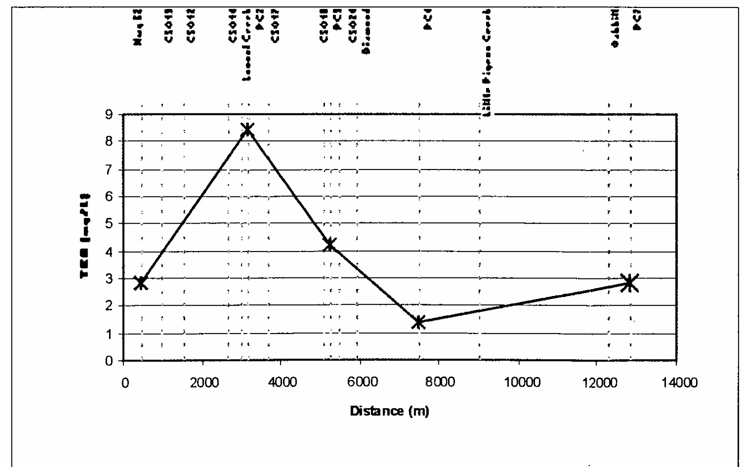


06/21/00 STORM EVENT



08/08/00 STORM EVENT



08/18/00 STORM EVENT

TOTAL KJELDAHL NITROGEN CONCENTRATIONS OVER STREAM LENGTH

PIGEON CREEK WATERSHED DIAGNOSTIC STUDY
EVANSVILLE WATER AND SEWER UTILITY AND
FOUR RIVERS RESOURCE CONSERVATION AND DEVELOPMENT AREA, INC.
Pigeon Creek, Indiana

HARZA ENGINEERING COMPANY
WATER & ENVIRONMENT

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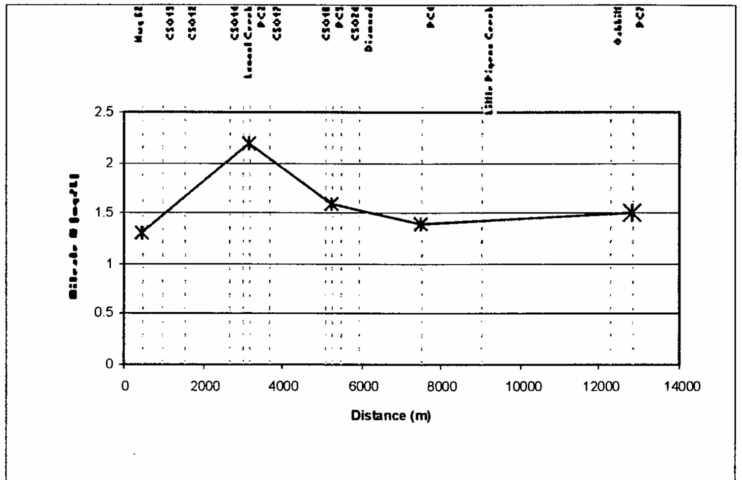

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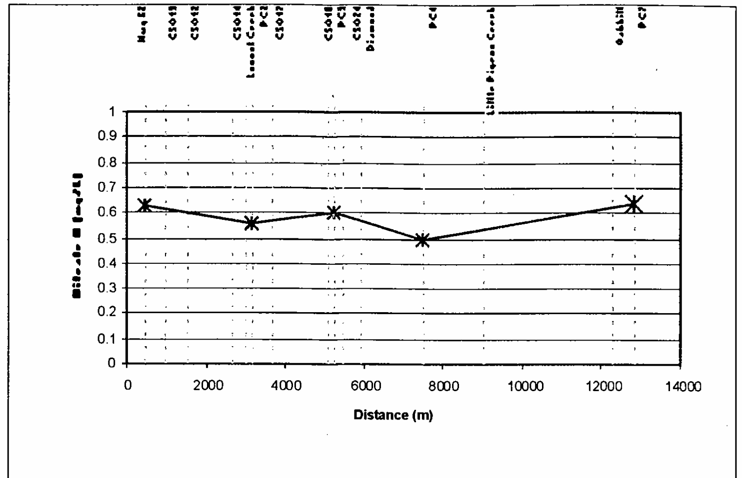
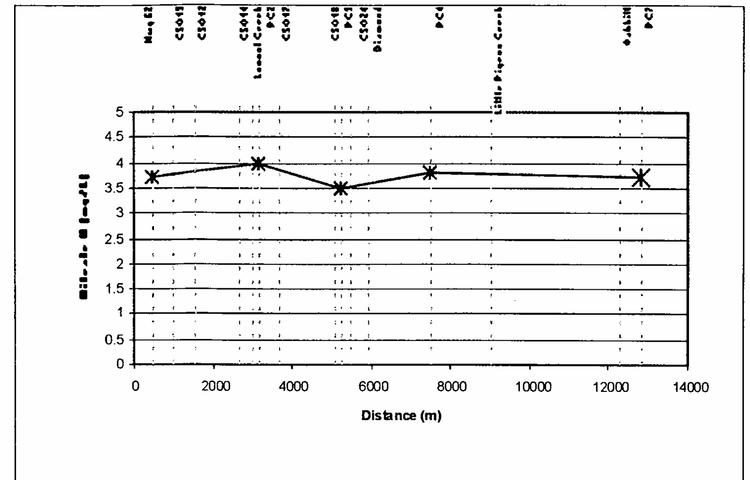
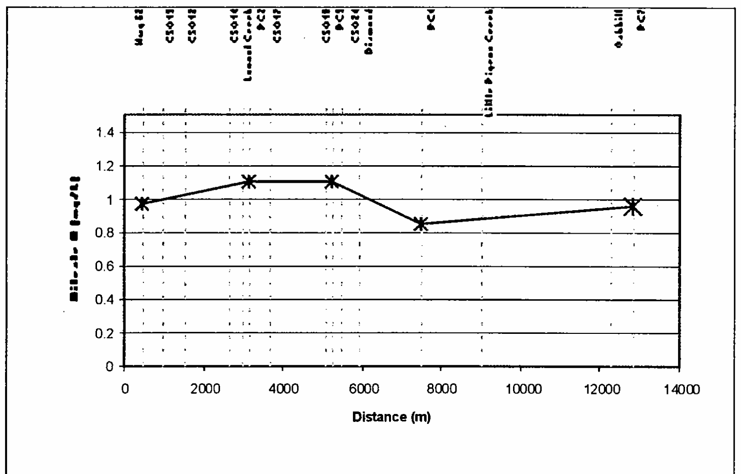


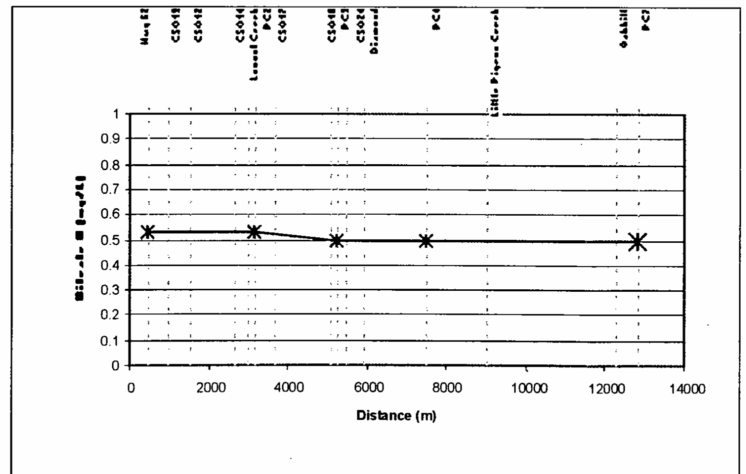
05/23/00 STORM EVENT



06/21/00 STORM EVENT



08/08/00 STORM EVENT



08/18/00 STORM EVENT

NITRATE CONCENTRATIONS OVER STREAM LENGTH

PIGEON CREEK WATERSHED DIAGNOSTIC STUDY
EVANSVILLE WATER AND SEWER UTILITY AND
FOUR RIVERS RESOURCE CONSERVATION AND DEVELOPMENT AREA, INC.
Pigeon Creek, Indiana

HARZA ENGINEERING COMPANY
WATER & ENVIRONMENT

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BIOTIC-ABIOTIC CORRELATION MATRIX

	Other Non-vegetated	Urban	Row Crop	Pasture	Undisturbed Uplands	Wetlands	Drainage area	Areal sediment loading	Areal phosphorus loading	FBI (Aug)	FBI (May)	Scrapers (Aug)	Scrapers (May)
Other Non-vegetated	1												
Urban	-0.1435	1											
Row Crop	-0.5634	-0.3108	1										
Pasture	0.6497	-0.0682	-0.8268	1									
Undisturbed Uplands	0.3254	0.5126	-0.8873	0.4955	1								
Wetlands	0.2872	-0.2770	-0.6616	0.6767	0.4349	1							
Drainage area	-0.1302	-0.0707	0.1229	-0.1705	-0.1825	0.2948	1						
Areal sediment loading	-0.3759	-0.3571	0.1290	0.0562	-0.2551	0.3876	0.0831	1					
Areal phosphorus loading	-0.3759	-0.3571	0.1290	0.0562	-0.2551	0.3876	0.0831	1	1				
FBI (Aug)	0.0906	-0.0204	-0.0144	0.1145	0.0084	-0.2063	-0.4143	0.0648	0.0648	1			
FBI (May)	0.2940	-0.2630	0.0913	0.2045	-0.3409	0.0220	0.2277	0.0171	0.0171	0.2582	1		
Scrapers (Aug)	0.1667	0.0890	0.1702	-0.1710	-0.0825	-0.4974	-0.4735	-0.4195	-0.4195	0.3822	0.1787	1	
Scrapers (May)	0.3326	-0.1158	0.1998	-0.1802	-0.2249	-0.2165	0.2589	-0.3354	-0.3354	0.0266	0.4752	0.1995	1
Filterers (Aug)	0.2179	0.2113	-0.3345	0.3233	0.2208	0.2180	0.0302	-0.0410	-0.0410	-0.6826	-0.2640	-0.2381	-0.1608
Filterers (May)	-0.2190	-0.3630	0.2405	-0.2189	-0.1256	-0.0599	-0.2650	0.1258	0.1258	0.0590	-0.4884	0.0262	-0.3044
Taxa Richness (Aug)	0.1276	-0.0976	-0.0593	-0.0211	0.0944	0.1033	-0.1846	0.1752	0.1752	0.2458	-0.2906	0.1425	-0.0884
Taxa Richness (May)	0.2439	-0.5073	0.0885	0.0345	-0.2029	0.2421	0.1580	0.1885	0.1885	-0.4153	0.2359	-0.2042	0.1978
EPT (Aug)	-0.0243	-0.0660	0.2902	-0.2396	-0.2974	-0.1981	0.0369	0.1239	0.1239	-0.6206	-0.2146	-0.0372	0.1504
EPT (May)	0.1193	0.0514	-0.2316	0.1046	0.2548	0.2200	-0.2312	0.0440	0.0440	-0.2094	-0.5599	-0.0048	-0.3416
Chironomids (Aug)	-0.2627	-0.2247	0.4201	-0.3686	-0.3390	-0.2309	0.1788	-0.0905	-0.0905	0.2961	0.2341	-0.0617	0.3538
Chironomids (May)	-0.4027	0.0466	0.3151	-0.3482	-0.2038	-0.2045	0.2291	-0.0289	-0.0289	-0.0531	-0.0021	0.0076	-0.1517
% Dominance (Aug)	-0.1072	0.0443	0.2869	-0.3324	-0.2428	-0.1756	0.3687	-0.0732	-0.0732	-0.5433	0.0506	-0.2489	0.2932
% Dominance (May)	-0.2402	0.2944	-0.0454	0.0070	0.0760	-0.0582	0.0925	-0.0573	-0.0573	0.0057	0.0702	0.1277	-0.2033
Shredders (Aug)	0.0041	0.2254	-0.1696	0.1154	0.0888	0.2321	0.4155	0.0087	0.0087	-0.2188	0.1340	-0.3084	0.2136
Shredders (May)	0.1358	-0.2332	0.0048	0.2068	-0.2050	0.1897	0.0080	0.0797	0.0797	-0.0272	0.2311	0.0192	0.0687
Silt (Aug)	-0.0549	0.1640	0.0055	0.0656	-0.0918	-0.0208	0.4153	-0.2409	-0.2409	-0.0804	0.2380	-0.3795	-0.0633
Silt (May)	-0.0089	0.0071	0.4069	-0.4028	-0.3709	-0.3584	0.2063	-0.0990	-0.0990	-0.2404	0.3681	0.0135	0.4198
Substrate (Aug)	-0.0474	-0.3052	0.0290	0.1048	-0.0665	0.0881	-0.3601	0.3074	0.3074	0.2514	-0.1918	0.2960	-0.0946
Substrate (May)	0.0252	-0.4877	0.0132	0.2122	-0.0917	0.1249	-0.5222	0.2941	0.2941	0.2885	-0.1424	0.2626	-0.1822

Exhibit 46 Page 2 of 2

BIOTIC-ABIOTIC CORRELATION MATRIX

	Filterers (Aug)	Filterers (May)	Taxa Richness (Aug)	Taxa Richness (May)	EPT (Aug)	EPT (May)	Chironomids (Aug)	Chironomids (May)	% Dominance (Aug)	% Dominance (May)	Shredders (Aug)	Shredders (May)	Silt (Aug)	Silt (May)	Substrate (Aug)
Filterers (May)	-0.0689	1													
Taxa Richness (Aug)	-0.0875	0.4943	1												
Taxa Richness (May)	0.2255	0.1854	0.2204	1											
EPT (Aug)	0.5543	0.0504	0.0564	0.4224	1										
EPT (May)	0.2558	0.3214	0.1631	-0.0881	0.1648	1									
Chironomids (Aug)	-0.4567	0.1120	-0.2402	-0.1555	-0.3694	-0.2476	1								
Chironomids (May)	-0.2041	-0.2946	-0.2751	-0.3633	-0.1020	-0.4596	0.0403	1							
% Dominance (Aug)	0.4014	-0.2290	-0.5171	0.2499	0.4179	0.0431	0.3590	-0.0671	1						
% Dominance (May)	-0.0058	-0.3742	-0.1987	-0.4046	-0.1989	-0.5322	-0.1787	0.6771	-0.2165	1					
Shredders (Aug)	0.1478	-0.5118	-0.2985	-0.0723	0.1276	-0.0227	0.0219	0.1704	0.2647	-0.1671	1				
Shredders (May)	0.0698	0.3813	0.1045	0.2289	0.0661	0.2442	0.1843	-0.5592	0.0114	-0.3950	-0.0173	1			
Silt (Aug)	-0.0668	-0.1025	-0.4426	-0.1481	-0.2797	-0.0854	0.2173	0.0702	0.1067	-0.1078	0.3526	0.2891	1		
Silt (May)	0.0203	-0.4041	-0.0943	0.4444	0.4013	-0.3611	0.0748	0.2329	0.4410	-0.1580	0.4156	-0.2235	0.0421	1	
Substrate (Aug)	0.0326	0.3042	0.3017	-0.2498	0.0804	0.0315	0.0275	0.0761	-0.2892	0.2643	-0.3693	0.0621	-0.6640	-0.4733	1
Substrate (May)	-0.0453	0.5210	0.2528	-0.1039	-0.0094	0.1757	0.0643	-0.1720	-0.3636	0.0199	-0.5519	0.2880	-0.5020	-0.5949	0.8805

Notes:

Shading indicates significant at or beyond the 0.05 level
Shading indicates significant at or beyond the 0.01 level

SUBWATERSHED RECOMMENDATIONS

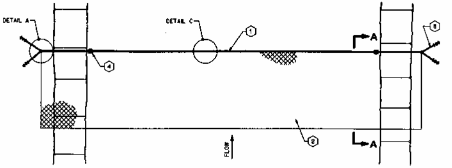
No	HUC	Name	% Row Crops	% Urban	Areal Sediment Loading (ton/ac/y)	Average QHEI	Average FBI	Comments	Recommendations
1	05140202040120	Pigeon Creek-Locust Creek (lower)	20%	20%	0.13	47.5	6.6	• CSOs and urban runoff are principal causes of pollution. Neither is represented in USLE estimate of sediment loading. • High coliforms in lower Locust Creek.	1. Preserve Pigeon Creek floodplain forest. 2. Prepare and implement LTCP for CSOs. 3. Implement urban and agricultural BMPs.
2	05140202040110	Locust Creek-Headwaters	18%	2%	0.19	51.0	6.7	• Poor riparian conditions. • Some steeper slopes (Fairpoint soils) may warrant special study and recommendations. • High coliform and nutrient concentrations.	1. Preserve remaining riparian corridors. 2. Institutionalize sustainable development guidelines. 3. Implement urban and agricultural BMPs.
3	05140202040100	Pigeon Creek-Kleymeyer Park	1%	64%	0.01	47.8	5.6	• CSOs and urban runoff are principal causes of pollution. Neither is represented in USLE estimate of sediment loading. • Second quartile in stream biotic integrity. • High nutrient concentrations.	1. Preserve Pigeon Creek floodplain forest. 2. Prepare and implement LTCP for CSOs. 3. Implement urban and agricultural BMPs.
4	05140202040080	Pigeon Creek-Harper Ditch	18%	31%	0.06	41.5	6.5	• Rapid growth area. • CSOs and urban runoff are principal causes of pollution. Neither is represented in USLE estimate of sediment loading. • High nutrient and coliform concentrations.	1. Preserve Pigeon Creek floodplain forest. 2. Institutionalize sustainable development guidelines. 3. Prepare and implement LTCP for CSOs. 4. Implement urban and agricultural BMPs.
5	05140202040010	Pigeon Creek-Crawford Brandeis Ditch	63%	11%	0.21	44.5	5.8	• Rapid urbanization of prime farmland. • Fourth quartile in stream biotic integrity	1. Institutionalize sustainable development guidelines. 2. Implement urban and agricultural BMPs.
6	05140202030060	Weinsheimer Ditch	61%	4%	4.03	34.5	6.3	• Fourth quartile in stream biotic integrity • Relatively high soil loss rate and stream siltation • Poor physical habitat • High nutrient and coliform concentrations.	1. Implement agricultural BMPs to reduce sheet erosion. 2. Restore riparian forest buffers. 3. Create treatment wetlands.
7	05140202030070	Pigeon Creek-Barnes Ditch	41%	3%	2.01	38.5	7.0	• Stollberg Ditch is very degraded due to Chandler WWTP. • Pigeon Creek has heavy siltation and high suspended solids concentrations. • Some steeper slopes (Fairpoint soils) may warrant special study and recommendations. • Drains some reclaimed mined land. • High coliform and nutrient concentrations at all stations.	1. Implement agricultural BMPs to reduce sheet erosion. 2. Improve operations at Chandler WWTP. 3. Preserve forested wetlands. 4. Create treatment wetlands.
8	05140202040060	Bluegrass Creek-Dennis Wagner Ditch	54%	0%	0.17	36.0	7.6	• Fourth quartile stream biotic integrity. • Poor physical habitat. • Drains some reclaimed mined land. • High nutrient concentrations and coliforms.	1. Implement agricultural BMPs. 2. Preserve remaining riparian corridors. 3. Preserve remaining forested wetlands. 4. Create treatment wetlands.
9	05140202040070	Bluegrass Creek-Firlick Creek	43%	3%	0.15	45.5	6.1	• Third quartile stream biotic integrity. • Poor physical habitat.	1. Implement agricultural BMPs. 2. Create treatment wetlands. 3. Create riparian buffers. 4. Restore Firlick Creek.
10	05140202040040	Bluegrass Creek-Stubbs Fruedenberg Ditch	34%	1%	0.15	43.0	6.7	• Poor stream habitat; fourth quartile stream biotic integrity. • Drains some reclaimed mined land.	1. Restore Bluegrass Creek & Stubbs Fruedenberg Ditch physical habitat in partnership with Bluegrass FWA.

SUBWATERSHED RECOMMENDATIONS

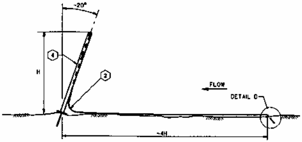
No	HUC	Name	% Row Crops	% Urban	Areal Sediment Loading (ton/ac/y)	Average QHEI	Average FBI	Comments	Recommendations
								• Newly created 2500-ac Bluegrass Fish and Wildlife Area. • High nutrient concentrations, coliforms.	2. Implement agricultural BMPs. 3. Create riparian buffers.
11	05140202040050	Schlensker Ditch	40%	3%	0.23			• Schlensker Ditch has been channelized. • No biological or water quality data available.	1. Restore Schlensker Ditch. 2. Implement agricultural BMPs, especially in Zanesville soils. 3. Create riparian buffers.
12	05140202040090	Little Pigeon Creek	16%	13%	0.08	46.2	5.8	• Airport located in subbasin 12. • Rapid urbanization of prime farmland. • Darmstadt WWTP • High coliforms and BOD, low DO, suggest unidentified pollutant source.	1. Implement airport runoff BMPs. 2. Implement agricultural and urban BMPs. 3. Institutionalize sustainable development guidelines. 4. Conduct additional diagnostic testing to identify source of coliforms and BOD.
13	05140202040030	Unnamed Tributary (Blue Grass Creek)	48%	0%	0.21			• No biological or water quality data available.	1. Implement agricultural BMPs. 2. Restore stream corridors.
14	05140202040020	Bluegrass Creek-Headwaters	50%	2%	0.22			• Elberfield WWTP • No biological or water quality data available.	1. Improve performance and/or upgrade Elberfield WWTP. 2. Implement agricultural and urban BMPs. 3. Institutionalize sustainable development guidelines.
15	05140202030040	Pigeon Creek-Clear Branch	25%	0%	2.17	54.2	5.6	• Drains some active and reclaimed mined lands. • Pigeon Creek degraded by Wabash and Erie Canal. • Significant forested wetlands remain. • Second quartile stream biotic integrity. • Some steeper slopes (Fairpoint soils) may warrant special study and recommendations. • High nutrient concentrations.	1. Study restoration of Pigeon Creek to original channel. 2. Implement agricultural BMPs. 3. Preserve bottomland forests and wetlands.
16	05140202030050	Squaw Creek	17%	0%	9.03	58.5	6.6	• High rate of soil loss. • Some steeper slopes (Fairpoint soils) may warrant special study and recommendations. • Squaw Creek is in the second quartile of biotic integrity. • High water conductivity and relatively high nutrient levels.	1. Implement agricultural BMPs. 2. Preserve bottomland forests and wetlands. 3. Preserve and expand Squaw Creek riparian corridors.
17	05140202030020	Big Creek-Little Creek/Plum Branch	19%	0%	6.92	58.0	6.3	• First quartile stream biotic integrity • Drains some active and reclaimed mined lands. • High rate of soil loss. • Some steeper slopes (Fairpoint soils) may warrant special study and recommendations. • High water conductivity.	1. Implement agricultural BMPs. 2. Implement mined land BMPs. 3. Preserve remaining wetlands and forests.
18	05140202030010	Big Creek-Headwaters	13%	0%	8.56			• No biological or water quality data available. • Drains some active and reclaimed mined lands. • Industrial (mine) discharge. • Lynnville WWTP and discharge. • Some steeper slopes (Fairpoint soils) may warrant special study and recommendations.	1. Implement agricultural BMPs. 2. Implement mined land BMPs. 3. Preserve remaining wetlands and forests.
19	05140202030030	Big Creek-Wye In RR (Pigeon Creek)	52%	0%	0.21	54.0	5.9	• Big Creek has been severely channelized, but is nevertheless in the first quartile of stream biotic integrity.	1. Implement agricultural BMPs. 2. Preserve remaining wetlands and forests.

SUBWATERSHED RECOMMENDATIONS

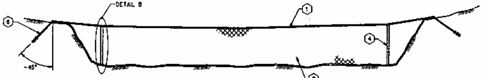
No	HUC	Name	% Row Crops	% Urban	Areal Sediment Loading (ton/ac/y)	Average QHEI	Average FBI	Comments	Recommendations
								• Extensive bottomland forested wetlands.	3. Protect and expand riparian corridors.
20	05140202020060	Smith Fork-Headwaters	48%	0%	1.14	50.8	6.6	• Industrial (mine) discharges. • Drains some active and reclaimed mined lands. • Despite extensive channelization of Smith Fork and tributaries, Smith Fork is in the first quartile of stream biotic integrity. • Some steeper slopes (Fairpoint soils) may warrant special study and recommendations.	1. Implement agricultural BMPs. 2. Implement mined land BMPs. 3. Preserve remaining wetlands and forests. 4. Protect and expand riparian corridors.
21	05140202020070	Smith Fork-Halfmoon Creek	66%	0%	0.24	48.5	5.8	• Smith Fork, Halfmoon Creek and tributaries have been severely channelized. • Oil wells. • Extensive wetlands along Pigeon Creek.	1. Implement agricultural BMPs. 2. Preserve bottomland forests and wetlands. 3. Preserve and expand Smith Fork & Halfmoon Creek riparian corridors.
22	05140202020050	Pigeon Creek-Snake Run	76%	0%	0.28			• Extensive channelization of Pigeon Creek and tributaries. • No biological or water quality data.	1. Implement agricultural BMPs. 2. Preserve bottomland forests and wetlands. 3. Preserve and expand riparian corridors. 4. Monitor compliance with floodway construction permit FW-20,093 special conditions.
23	05140202020030	Hurricane Creek Ditch	74%	3%	4.90	42.0	7.0	• Haubstadt Municipal WWTP is poorly operated. Upgrading is planned for 2001. • Some steeper slopes (Alford soils) may warrant special study and recommendations. • High nutrient and coliform concentrations. • DO supersaturation and high pH imply eutrophy.	1. Complete upgrading of Haubstadt WWTP. Provide increased training opportunities for operators. 2. Implement agricultural BMPs,. 3. Preserve bottomland forests and wetlands. 4. Preserve and expand riparian corridors. 5. Prepare nutrient management plans.
24	05140202020040	West Fork Creek	88%	3%	9.45	41.2	6.3	• Fort Branch WWTP and discharge. • Industrial NPDES discharge. • Affected by Haubstadt WWTP • Some steeper slopes (Alford soils) may warrant special study and recommendations. • Streams channelized and riparian buffers almost nonexistent. • High nutrient and coliform concentrations.	1. Implement agricultural BMPs. 2. Create riparian corridors and nutrient management plans. 3. Study wet weather discharges at Fort Branch WWTP
25	05140202020020	Pigeon Creek-Clear Fork Ditch	80%	4%	13.18	45.7	6.4	• While streams have been channelized, this subwatershed is in the first quartile stream biotic integrity. • Some steeper slopes (Alford soils) may warrant special study and recommendations. • High nutrient concentrations.	1. Implement agricultural BMPs. 2. Create riparian corridors and nutrient management plans.
26	05140202020010	Sand Creek-Muddy Fork Ditch	79%	1%	2.25	39.0	6.4	• Some steeper slopes (Alford soils) may warrant special study and recommendations. • Even though Sand Creek has been channelized extensively, it ranks in the top quartile of biotic integrity.	1. Implement agricultural BMPs. 2. Create riparian corridors and nutrient management plans.



PLAN
(NTS)



SECTION A–A
(NTS)



PROFILE
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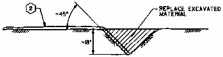
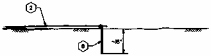
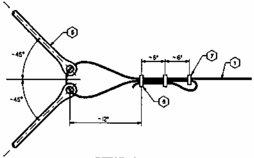


ALTERNATIVE A

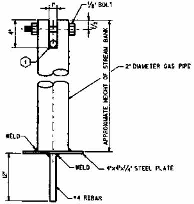


ALTERNATIVE B

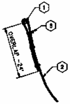
DETAIL D
(NTS)



DETAIL A
(NTS)



DETAIL B
(NTS)



DETAIL C
(NTS)

Site Selection

The dam should be constructed in a location where the incised channel narrows and the upstream flood plain is broad. These parameters will minimize the amount of materials necessary to construct the dam and maximize the overbank flood storage and wetland habitat. The dam should be constructed perpendicular to the channel with the maximum cable sag in the center of the channel, which should prevent high flows from attacking the stream banks.

The height, at the point of maximum cable sag over the stream channel should not exceed five feet. However, some allowance should be given for the additional cable sag after the dam is fully loaded with sediment. Accordingly, the distance between the maximum sag and the stream channel might initially be as much as six or seven feet. The cable is expected to sag in the vertical direction as well as bow in the downstream direction. These deformations are due, in part, to cable stretch and tie end soil anchor deformation.

Site Preparation

The ground along the alignment of the cable should be cleared of woody vegetation. The clearing, however, should be kept to a minimum in order to maintain the vegetation of the site. Woody vegetation upstream of the cable should be cleared to facilitate the placement of the chain link fence.

Dam Construction

The soil anchors should be installed at a 45-degree angle of each other. The heads of the anchors, once completely augered into the ground, should abut to each other in order to maintain equal force on each anchor.

The chain link fence facing of the dam should be draped over the cable and attached to itself with reinforcing bar tie wires. The chain link fence should run upstream a length equal to about 4 times the height of the dam, maintaining contact with the streambed the entire length. The upstream ends of the chain link fence should be secured in an excavated trench or by J-hooks made from #3 rebar. The seam between runs of chain link fence should be tied with reinforcing bar tie wires.

Parts List

1. Steel Cable, 3/8" to 1/2" diameter
2. Galvanized Chainlink Fencing
3. Reinforcing Bar Tie Wire
4. Stanchion
5. Soil Anchors, 48" long
6. Cable Clamps, 1/2 to 3/4
7. Cable Clamps, 3/8 to 1/2
8. J-hook, #3 rebar

CABLE DAM

GENERIC PLAN, PROFILE, SECTION AND DETAILS

HARZA